modern castings

AFS NOVEMBER, 1959

Editorial Dept.
University Microfilms
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Ann Arbor, Mich.

- Read about New Polymer Sand Binder Used to Make Mold Shown Above.
- Pattern Engineering is Like a Three-Legged Stool.
- Sailor-Foundrymen Keep Navy on the Go.
- Helium Snorkeling Helps Vacuum Degassing of Steel.
- Can Casting Design Cure Built-in Unreliability?
- Ford Motor Co. Relies on Shell Molding.

THE BAFFLING CASE OF THE FAULTY BLOWERS

Another costly mystery solved–by the man from Kaiser Aluminum

THE PUZZLING FACTS. A good customer of Kaiser Aluminum had troubles. He manufactured a large blower casting which was to be used at high speeds. But inspection revealed that the casting had numerous cold shuts. The part was unsatisfactory. What to do?

HOW THE CASE WAS SOLVED. It looked like a tough problem, but the man from Kaiser Aluminum found an "out." He discovered that improper gating design was the villain. Redesigning the gating eliminated the difficulty and the case was solved.

WE LOVE A MYSTERY. This is one of many actual cases solved by Kaiser Aluminum working with a customer. Perhaps *you* have a mystery one of our technical engineers might help solve? He's ready to give you expert advice on any casting problem—including mold and die design, alloy selection, heat treatment, finishing, fluxing, metal transfer.

FULL ALLOY AVAILABILITIES. Kaiser Aluminum can supply you *fast* with a wide selection of casting alloys to suit any engineering requirement—from general purpose, low stressed alloys to high purity alloys having good properties at elevated temperatures.

FOR PIG AND INGOT with a free sleuthing bonus, call your nearest Kaiser Aluminum sales office now. Or write to: Kaiser Aluminum & Chemical Sales, Inc., 1924 Broadway, Oakland 12, California.

KAISER ALUMINUM
THE BRIGHT STAR OF METALS

See "MAVERICK" • Sunday Evenings, ABC-TV Network • Consult your local TV listing.

THOUSANDS OF CarVer RAPID MULLERS NOW IN USE

The most POPULAR, most PRACTICAL muller on the market . . . Here's why . . .

- **The fastest! A batch every 75 seconds!**
- **Absolutely *no* lumps or wet spots!**
- **Easiest to clean! Just reach inside**
- **Only *one* moving part . . . no maintenance worries!**
- **3 times lower initial investment than with most mullers!**
- **Works equally well with *any* kind of binder!**

IF YOU COMPARE MULLERS CAREFULLY . . . YOU'LL CHOOSE CARVER

Only* CarVer *Has Everything For the CO_2 Process!

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CARVER Automatic Gassing Apparatus

KRAUSS Taper Slot Core Vents

STEINEX available only from CARVER

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Muscatine, Iowa

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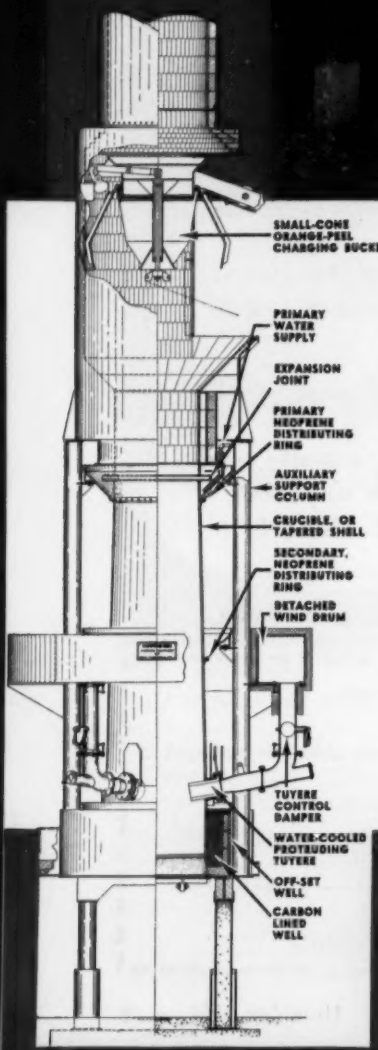
Circle No. 146, Page 15 or 145

MODERN Water-Cooled Cupolas for FLEXIBILITY



No. 48-WC and No. 54-WC, controlled slag, externally, water-cooled cupolas at Neenah Foundry — operating with basic, acidic or neutral slags as desired.

JOBBING FOUNDRIES CAN AFFORD IT, TOO!

"can't afford not to MODERNIZE," is the reason as given by Neenah Foundry Company for their change to controlled-slag, externally, water-cooled cupolas. Operating with protruding copper, water-cooled tuyeres and melting directly against the steel shell over-all benefits include:

- ***Greater flexibility and closer control of the melting processes . . .***
- ***Prolonged periods of melting . . .***
- ***Decreased costs for refractory and maintenance . . .***

These major advantages and many more are being enjoyed throughout the major industries and by foundries large and small.

At Neenah Foundry the 8 and 11 TPH MODERN, water-cooled cupolas are operated with basic, acidic or neutral slags as desired. Cupolas remain in continuous operation from Monday morning 'til Friday night. All types of gray iron melted along with base iron for nodular.

All these and other benefits are covered in new bulletin 149-A. Use the coupon or write to Modern Equipment Co., Port Washington, Wis.

MODERN

NEW
Catalog 149-A
Mailed on Request

Modern Equipment Co., Dept. MC-11, Port Washington, Wis.
☐ Mail to my attention new catalog 149-A. ☐ Mechanical charging ☐ Dust abatement control ☐ Pouring equipment

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My Name .....

Circle No. 147, Page 18 or 143

modern castings

the technical magazine of the metalcasting industry

november, 1959
vol. 36, no. 5

features

NEW POLYMER SAND BINDER by J. L. Dewey and T. J. West 34
Something new has appeared on the horizon for improving green sand properties . . . especially suited to steel casting.

PROOF OF PRODUCT IS IN THE CASTINGS by J. H. Schaum 34
Crucible Steel Castings Co. tells success story of benefits derived from use of new polymer sand binder.

PATTERN ENGINEERING by P. B. Croom 38
When the casting buyer, patternmaker and foundryman manage to get together in advance, well engineered castings result.

SAILOR-FOUNDRYMEN by J. Hurlburt 42
Our U.S. Navy has to depend on floating foundries to keep the fleet operational away from home. Here's how they do it.

A PENNY A POUND KNOCKS THE H_2 OUT OF STEEL 45
World's first production-type ladle vacuum degassing system is given it's premier showing to the metalcasting industry.

CASTING DESIGN . . A MODERN ART by A. R. Moore 46
Is the suspicion of castings justified? Is unreliability an integral part of castings? Where does unreliability originate?

SHELL MOLDING DEVELOPMENTS IN THE AUTOMOTIVE INDUSTRY by H. C. Grant 641
Ford Motor Co. tells about the benefits of shell molding in three foundries, in machine shops and to the product engineers.

INDIRECT ARC ELECTRIC FURNACE PRODUCTION OF DUCTILE IRON by L. Miller 653
This melting unit is simple to operate and handles a variety of alloys. Article also details use of new plunger ladle.

ACID CUPOLA MELTING FOR DUCTILE IRON by H. E. Henderson 661
Calcium carbide injection is used by Lynchburg Foundry Co. to remove sulphur from acid cupola iron.

BASIC CUPOLA MELTING OF DUCTILE IRON by J. T. Williams 669
Here's a good comparison between acid and basic cupola operation showing the pros and cons of the two techniques.

RAMMING, SUPERHEAT AND ALLOYS (TYPE OF METAL) EFFECTS ON METAL PENETRATION: REPORT OF AFS SAND DIVISION MOLD SURFACE COMMITTEE 8-H PREPARED by G. J. Vingas 671
Experiments with aluminum, brass, gray iron, steel and Wood's metal tie down the causes of metal penetration into sand.

COMPARISON OF X-RAY QUALITY AND TENSILE PROPERTIES IN CAST HIGH STRENGTH STEEL by H. R. Larson, H. W. Lloyd and F. B. Herlihy 676
High integrity steel castings for aircraft lose ductility when the slightest microshrinkage is present.

APPLICATION OF THEORY IN UNDERSTANDING FLUIDITY OF METALS by J. E. Niesse, M. C. Flemings and H. F. Taylor 685
A vacuum fluidity test coupled with high speed photography reveals importance of mode of solidification on fluidity.

CAST LOW ALLOY STEELS DUCTILITY AND TOUGHNESS, REDUCED PHOSPHORUS AND SULFUR CONTENT SIGNIFICANCE by J. Zotos 698
By reducing the sulfur and phosphorous content of different steels, marked improvement in physical properties result.

featurettes

REDUCING BLAST CLEANING COSTS by G. O. Pfaff 152

AIR-SET PROCESS by D. R. Chester 153

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NATIONAL LP Air CONVEYOR IN ACTION

View from sand bin shows pipe carrying sand to discharge. Note spilled sand, from clamshell operation, at upper left. Air-Conveyor system provides waste-free delivery.

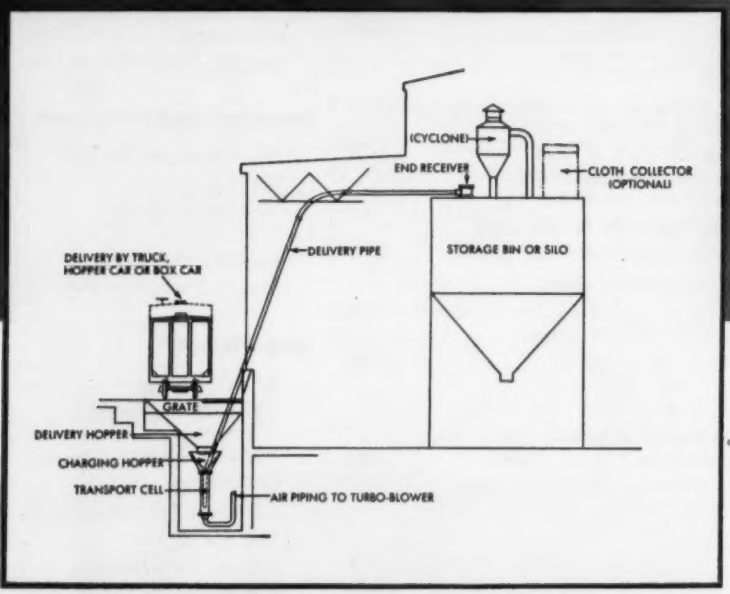
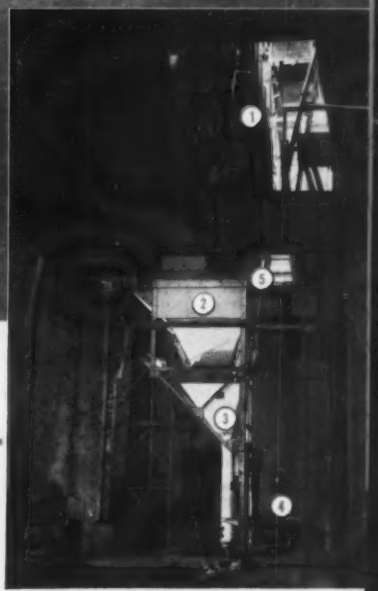


Diagram shows general arrangement of LP Air-Conveyor system for dry sand delivery by truck, hopper car or box car. System also has many uses *within* the foundry.



View from below track showing (1 hopper car, (2) charging hopper, (3 transporter, (4) turbo-blower, and (5 delivery pipe.

How STUDEBAKER-PACKARD saved $12,950 on Sand Delivery Costs

Low cost, low pressure National System slashes maintenance costs, automates dry sand delivery

PROBLEM:

A brisk demand for Studebaker *Larks* had the Studebaker-Packard Corp. foundry at South Bend, Indiana, going at near-capacity. An important sand dryer requiring repair expenditures of $5000 threatened a bottleneck.

SOLUTION:

National recommended the trial of a new low cost, low pressure air-conveyor system for the delivery of new sand. These advantages were cited:

- *Eliminate need for the dryer.* Makes possible dry sand delivery by closed hopper car; eliminating need for dryer and for troublesome paper car covers.
- *Eliminate need for clamshell.* Sand to be discharged direct from car to unit under track, then transported continuously and automatically direct to storage bin, hoppers or belt conveyor.
- *Save time, labor and maintenance* of crane operation. Air-Conveyor is compact, simple and a fully automated system.

As a result of these recommendations, the National LP system was installed.

RESULTS:

During one year of Air-Conveyor operation, Studebaker has:

- Abandoned earlier plans (and need) to overhaul sand dryer. Savings: **$5,000**
- Reduced annual maintenance costs on clamshell system. Savings: **$1,200**
- Eliminated need and labor involved with paper car covers. Savings: **$6,750**

$12,950 represents only an immediate tangible savings to Studebaker. In addition, the Air-Conveyor system now provides all dry sand for core mixers; has reduced manpower requirements; has considerably reduced sand unloading time and contributed to the general improvement of the operation. A second unit, now being installed, will further increase Studebaker's overall savings.

The National LP unit is described at lower left and shown in the photos. It is simple, completely versatile, adaptable to many foundry jobs and occupies but a fraction of the space required for almost any unit it may replace. Its basic cost is considerably less than the amount Studebaker *saved* in one year.

Got a job for Air-Conveyor? Write *National* for further details on either low (LP) or high pressure (HP) Air-Conveyor systems.

NATIONAL Air CONVEYOR CORPORATION

A subsidiary of National Engineering Company

630 Machinery Hall Building

Chicago 6, Illinois

Circle No. 148, Page 15 or 145

SAND CONDITIONING TOPICS

PUBLISHED BY ROYER, MANUFACTURERS OF THE FOREMOST IN SAND CONDITIONING EQUIPMENT

ROYER

Sand, from a central conditioning station . . .
moves by tractor in a front-end loader to . . .
Model NYP-E Royer for cooling, aerating and fluffing at the molding station for maximum benefits.

THERE IS A SAND CONDITIONING SYSTEM TO FIT YOUR BUDGET . . .

Here is a positive cost-cutting sand conditioning system that falls within the budget limitations of the small or medium semi-mechanized foundry. It delivers better sand without adding to time or manpower requirements, and without the expense of complete mechanization. It gains the advantages of fluffing after handling, as the final step at the molding station.

Teamed with front-end loader, this Royer NYP-E Portable moves from floor to floor in this grey iron foundry. What used to be caked, packed sand from mulling is now a cool, fluffy pile.

An integral part of this practical system is the Royer Model NYP-E Sand Separator and Blender. It can be moved swiftly from station to station, delivering cooled, aerated, fluffed, perfectly conditioned sand right where it's wanted. With this Royer you can really get all the advantages of central system sand control.

Your system is probably "different." There's still a versatile unit of the Royer "NY" Series to fit it . . . and improve it. As a stationary model, the "NY" will fit into a conveyor system, or can be installed to take the discharge of stiff sand directly from your muller. However you use it, the Royer vastly improves sand, saves time and money, improves yield and quality of castings —all at a fraction of a cent per ton of sand.

We'll be happy to have an experienced, foundry-wise Royer agent call to help you work out the system that's best for your operation. Or, if you prefer, we'll rush you a copy of Bulletin NY-54, giving further information about these units and how you will benefit from them. When you're convinced, *you* can call in your Royer agent and take the first step towards better sand with a Royer system.

ROYER FOUNDRY & MACHINE CO.

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☐ Rush me a copy of Bulletin NY-54.

NAME_____
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Circle No. 149, Page 13 or 145

future meetings and exhibits

Nov. 2-5 . . American Institute of Mining, Metallurgical & Petroleum Engineers, *Fall Meeting.* Morrison Hotel, Chicago.

Nov. 2-6 . . Society for Nondestructive Testing, *Annual Convention.* Hotel Hamilton, Chicago.

Nov. 2-6 . . American Society for Metals, *National Metals Exposition & Congress.* International Amphitheatre, Chicago.

Nov. 3-4 . . Investment Casting Institute, *Annual Meeting.* LaSalle Hotel, Chicago.

Nov. 5-6 . . National Foundry Association, *Annual Meeting.* Roosevelt Hotel, New York.

Nov. 9-11 . . Steel Founders' Society of America, *Technical & Operating Conference.* Carter Hotel, Cleveland.

Nov. 16-20 . . *International Automation Congress & Exposition.* New York Trade Show Building, New York.

Nov. 20-21 . . AFS *East Coast Regional Foundry Conference.* Statler-Hilton Hotel, New York.

Dec. 2 . . Foundry Facings Manufacturers Association, *Annual Meeting.* Hotel Waldorf-Astoria, New York.

Dec. 2-4 . . Metallurgical Society, American Institute of Mining, Metallurgical & Petroleum Engineers, *Electric Furnace Conference.* Sheraton-Cleveland Hotel, Cleveland.

Dec. 2-4 . . National Association of Manufacturers, *Annual Meeting.* Waldorf-Astoria Hotel, New York.

Dec. 15 . . Material Handling Institute, *Annual Meeting.* Savoy-Hilton Hotel, New York.

1960

Jan. 15 . . Malleable Founders Society, *Semi-Annual Meeting.* Hotel Sheraton-Cleveland, Cleveland.

Jan. 25-28 . . *Plant Maintenance & Engineering Show.* Convention Hall, Philadelphia.

Feb. 11-12 . . AFS *Wisconsin Regional Foundry Conference.* Hotel Schroeder, Milwaukee.

Feb. 14-18 . . American Institute of

Continued on page 8

Every single piece made using one Cities Service Core Oil!

From the size of a pin to the size of a truck engine, Cities Service Delco 60 makes them all!

The way Fred Weir has expanded the uses of one core oil is typical of the way he's expanded his entire business.

In 1941, Weir Foundry consisted of a one-car garage. Today, its modern plant pours ten tons of metal a day, and its castings include parts for food choppers, dough mixers, dishwashers, road machinery, plumbing fixtures, door assemblies, pumps, and paper cutters.

The Weir Machine & Foundry Co. is particularly proud of two things: the Nicast process (licensed from International Nickel Co.) by which they produce castings resembling stainless steel and the success they have had with Cities Service Delco 60 Core Oil.

A good many people have doubted the ability of any core oil, no matter how good, to accomplish the many jobs shown above. But under the supervision of Charles Fish, the core room foreman, they were proven wrong. Says Mr. Fish: "The uniformity of Delco 60 and its astounding versatility have been a factor in our growth. There seems to be nothing the oil can't do . . . and its baking and shake-out qualities are always excellent."

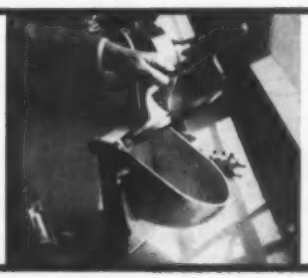
As a tribute to their versatility, Weir Machine & Foundry Co., Inc. was recently awarded a license to produce Ductile Iron castings to further extend their services to their customers.

Again and again, where cores are intricate, production diversified, and schedules tight—you'll find Cities Service Delco Core Oils. Find out what they'll do for you. Talk with a Cities Service Core Oil Specialist. Or write: Cities Service Oil Company, 20 North Wacker Drive, Chicago 6, Illinois.

CITIES SERVICE

QUALITY PETROLEUM PRODUCTS

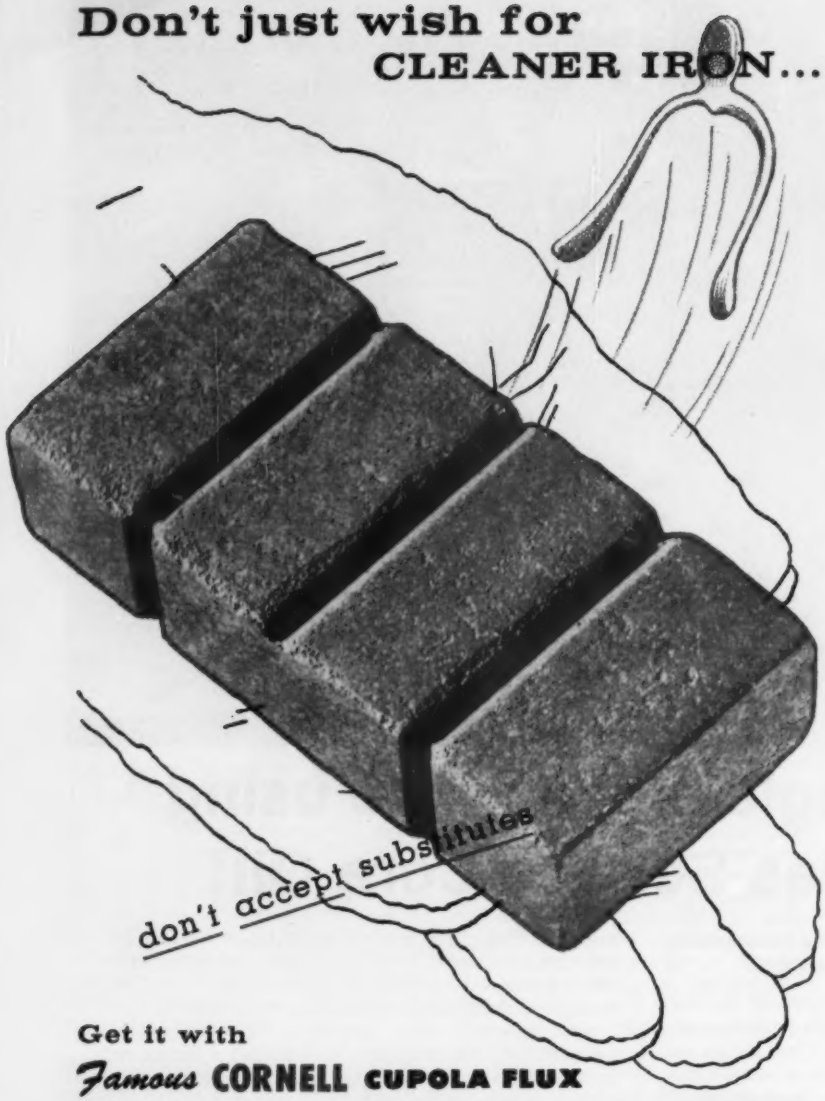
. . . and it all started in a garage. Weir's modern foundry, pouring ten tons of castings per day, is a far cry from the one-car garage in which the business began in 1941.



Nicast Process, licensed to Weir by International Nickel Company, produces food machinery castings with remarkable finish. Weir is one of the two licensees in the state.

Circle No. 150, Page 13 or 145

Don't just wish for CLEANER IRON...



Get it with

***Famous* CORNELL CUPOLA FLUX**

for Gray Iron and Malleable Iron Foundries

Wherever you go, foundrymen will recommend Famous Cornell Cupola FLUX. That's because this is the one flux that brings results day after day. The reason? Famous Cornell Cupola FLUX is a scientifically prepared mixture of high grade minerals and other materials which create a chemical reaction in molten iron by greatly increasing slag flow off. Iron is always cleaner. Write for Bulletin 46-B.

If you melt aluminum, copper or brass, try Famous CORNELL Aluminum, Copper or Brass Flux. Write for Bulletin 46-A.

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Circle No. 151, Page 15 or 145

future meetings

Continued from page 6

Mining, Metallurgical & Petroleum Engineers, *Annual Meeting*. New York.

Feb. 18-19 . . AFS *Southeastern Regional Foundry Conference*. Hotel Thomas Jeffereson, Birmingham, Ala.

Feb. 22-24 . . Material Handling Institute, *Pacific Coast Show*. Cow Palace, San Francisco.

Feb. 24-25 . . Malleable Founders Society, *Technical & Operating Conference*. Cleveland.

March 7-8 . . Steel Founders' Society of America, *Annual Meeting*. Drake Hotel, Chicago.

March 14-18 . . National Association of Corrosion Engineers, *Annual Conference*. Dallas, Texas.

March 16-17 . . Foundry Educational Education, *Annual College-Industry Conference*. Statler-Hilton Hotel, Cleveland.

April 3-8 . . American Chemical Society, *Spring Meeting*. Detroit.

April 13-14 . . Malleable Founders Society, *Market Development Conference*. Edgewater Beach Hotel, Chicago.

April 21-28 . . American Society of Tool Engineers, *Annual Meeting & Tool Show*. Municipal Auditorium, Detroit.

April 24-28 . . American Ceramic Society, *Annual Meeting*. Bellevue-Stratford Hotel, Philadelphia.

April 26-29 . . National Industrial Sand Association, *Annual Meeting*. Key Biscayne, Fla.

May 9-13 . . AFS *64th Annual Castings Congress & Foundry Show*. Convention Hall, Philadelphia.

June 26-July 1 . . American Society for Testing Materials, *Annual Meeting & Exhibit*. Chalfonte-Haddon Hall, Atlantic City, N. J.

Sept. 11-16 . . American Chemical Society, *Fall Meeting*. New York.

Sept. 19-20 . . Steel Founders' Society of America, *Fall Meeting*. The Homestead, Hot Springs, Va.

Sept. 19-24 . . *International Foundry Congress*. Zurich, Switzerland.

Oct. 12-14 . . Gray Iron Founders' Society, *Annual Meeting*. Netherland-Hilton Hotel, Cincinnati.

AFS Chapter meetings for November appear on page 126

Circle No. 152, Page 15 or 145

BIG NEWS

AND THAT'S N

HYDRA-MOLD

Learn About Your Stake in B&P Research

Shown here is the Rol-A-Draw station of the new 9,000 lb. Hydra-Mold unit installed at the Atlas Foundry & Machine Company at Tacoma, Washington. Hydra-Slinger-rammed mold sections weighing up to 9,000 lbs. are rolled over directly from the Roto-Mold turntable (see drawing) and patterns are precisely drawn. Then patterns are returned directly to the table ready for the next molding cycle. Four patterns are handled on the Hydra-Mold at the same time, and changes may be made without interrupting operations.

The all-hydraulic operation of the Hydra-Slinger, Roto-Mold turntable and Rol-A-Draw machine is extremely fast and accurate. New, intersecting, Roto-Mold Rol-A-Draw design completely eliminates the movement of rammed molds into the Rol-A-Draw and the movement of patterns from the Rol-A-Draw to the turntable. Four men handle the entire operation on the Atlas unit, although that manning can be changed to meet production requirements without affecting efficiency.

The complete Atlas story is told in the current issue of BETTER METHODS magazine; ask for your free copy. Beardsley & Piper Div., Pettibone Mulliken Corporation, 2424 North Cicero Avenue, Chicago 39, Illinois.

SEND CARD NOW!

Sure I'm interested in your research and its results! Send me the whole story on:*

HYDRA-MOLD UNITS ☐ **SHELL CORE UNITS** ☐

CO_2 FLEXIGAS UNITS ☐ **CORE ROLL-OVER UNITS** ☐

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**NO OBLIGATION OF ANY KIND*

NOT ALL! LOOK AT THESE

BIG NEWS FROM B&P

A NEW ALL-HYDRAULIC MOLDING UNIT WITH SERIES H ROL-A-DRAW

occupies LITTLE space . . . does BIG things

The need existed; foundrymen everywhere wanted an easy-to-operate, easy-to-install, complete molding unit with *real flexibility and capacity.* B&P engineers went to work on the problem. The result was the new HYDRA-MOLD with all-hydraulic Roto-Mold turntable, Hydra-Slinger and Rol-A-Draw. It provides everything foundrymen wanted . . . and more.

Have space problems? A complete unit with 15,000 lb. capacity requires only 18 x 31 feet.

Need flexibility? The largest Hydra-Mold handles molds or core boxes up to 54 x 90 inches—draws to 28 inches. Instant pattern changes!

Need productivity? A single Hydra-Mold provides the production of four big fully-rigged machine stations at a fraction of the installation and operating cost.

Worried about costs? Hydra-Mold manning may be varied to meet the level of operation without loss of efficiency . . . costs kept in line over a wide range of capacity conditions.

All this and *low, low installation costs, too!* No pits required—single sand delivery system—no pattern or flask changeover—single, simple mold and flask conveyor system and many other advantages.

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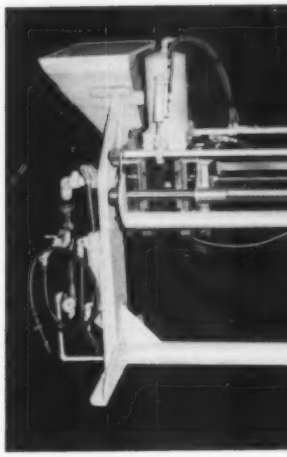


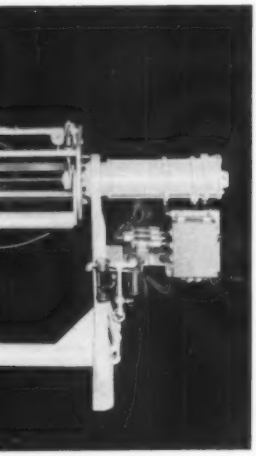
A New Core

A New CO_2

NOT ALL! LOOK AT THESE

MAJOR NEW DEVELOPMENTS . . .

Shell Core Units That Really Shell Out!



Speaking of shell cores, the new SF-6A CORMATIC Hollow Shell Core Machines deliver fully cured, ready-to-use, precise cores at lower cost than any other available units. A push-button-operated, completely automatic version, the SF-6A, is the most productive single-station unit yet developed. Both are results of B&P's intensive research and development program.

One man easily operates three of the automatic units to provide truly outstanding production at a fraction of the investment for similar productivity with other methods. Not only that, but with three single-station machines, three different size cores with different production time cycles can be produced at top efficiency. No necessity to slow the whole operation because one core requires a longer baking cycle. Box changes or maintenance can be accomplished on one unit at a time, without affecting the high production rate on the other units. More flexibility to meet varying production requirements, too.

re Rollover Machine That Rolls Up New Records!

Here's the rollover-draw machine to keep pace with the highly productive FLEXIBLO and SAN-BLO core blowers (and other core production units). The NCR ROL-A-COR, available in three sizes with capacity to 1,000 lbs., is assurance that modern core blowers work at most productive rates. The NCR ROL-A-COR not only speeds handling of cores, but provides an extremely accurate draw, rolls over and ejects. It will handle any box within its broad range without clumsy, time consuming machine adjustments, too.

CO_2 Unit That Takes the Guessing Out of Gassing!

This operator is producing *completely cured CO_2 cores* at an oil-sand core production rate. How?—the new FLEXIGAS core gassing machines! Two FG-5-10 FLEXIGAS machines provide a balanced operation when teamed with the highly productive CB5 FLEXIBLO core blower.

FLEXIGAS core gassing machines feature automatic gassing cycle, full 4" clamping stroke and simple push button operation.

Now, whatever your requirements may be, with a very modest investment, you can use the CO_2 process on a *real* production basis.

Use this card to learn about your stake in B & P research

"Better steel tire molds at greater savings with NATIONAL* Western Bentonite"

The Lectromelt Casting Division of Akron Standard Mold Company have proved they can produce better steel tire molds—At A Greater Savings—using NATIONAL Western Bentonite in their molding sands.

NATIONAL Western Bentonite in molding sands produces finer finished castings of all metals: malleable iron, grey iron, steel, brass, aluminum, or magnesium.

Use NATIONAL Western Bentonite for good molding, for better cores and high-refractory core wash formulations. Cores dry better, have higher dry strength, and contain less gas to vent.

BAROID

BAROID CHEMICALS, INC.

A SUBSIDIARY OF NATIONAL LEAD COMPANY

1809 SOUTH COAST LIFE BLDG. HOUSTON 2, TEXAS

56E3

*Registered Trademark, National Lead Company

Circle No. 153, Page 15 or 145

For over 70 years, Pittsburgh Crushed Steel Company has consistently led the metal abrasives industry—has led in research and product development—has led in the improvement of production methods—and has led in sales and service facilities as well as in distribution facilities!

The results have been better metal abrasives for lower cleaning costs in foundries, forge plants, and steel and metal working plants in general!

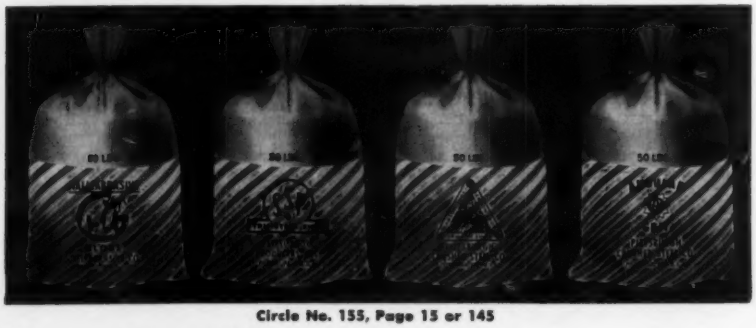
Today, through 13 distributing points and 33 sales-service offices, we supply all sizes and types of metal abrasives, iron and steel, for every type of blast-cleaning equipment and for every blast-cleaning requirement!

Our engineering, sales, and service representatives are always available to you in connection with your blast-cleaning needs.

PITTSBURGH CRUSHED STEEL COMPANY

Arsenal Sta. Pittsburgh (1), Pa.
Subsidiaries: Globe Steel Abrasive Co., Mansfield, Ohio
Steel Shot Producers, Arsenal Sta. Pittsburgh, Pa.

MALLEABRASIVE | TRU-STEEL SHOT | SAMSON SHOT | ANGULAR GRIT



Circle No. 155, Page 15 or 145

Have you read?

Alloying and Heat Treating Ductile Cast Iron. U. S. Dept. of Commerce, Office of Technical Services. U. S. Government Printing Office. Washington, D.C. (1935) PB 131350. 89 p.

Army Ordnance was concerned with the basic variables involved in risering ductile iron castings. These were determined and measurements were made of their effects on shrinkage. Gross and sponge-type shrinkage were encountered and investigated. Risering for gross shrinkage was accomplished by engineering a riser to remain liquid as long as needed, to contain adequate feed metal, and to be within proper feeding distance. The amount of gross feed metal required depended upon carbon content, silicon content, pouring temperature and rigidity of mold.

Sponge type shrinkage was found to be caused by lack of adequate graphite precipitating.

Determination of how and where the principles of machinability applied to ductile cast iron constituted a second part of the report.

Metal Castings, Morris, J. L., Prentice-Hall, Englewood Cliffs, N. J. 1957. Describes and discusses most of the current and potentially valuable casting methods supplemented with a bibliography and an index. The 296 pages run the gamut from molding sand and design of patterns to quality control in die casting and welding. Photographs and line drawings support this particular casting story.

Nondestructive Testing Handbook . . . The Ronald Press Co., 15 East 26th St., New York. 1959.

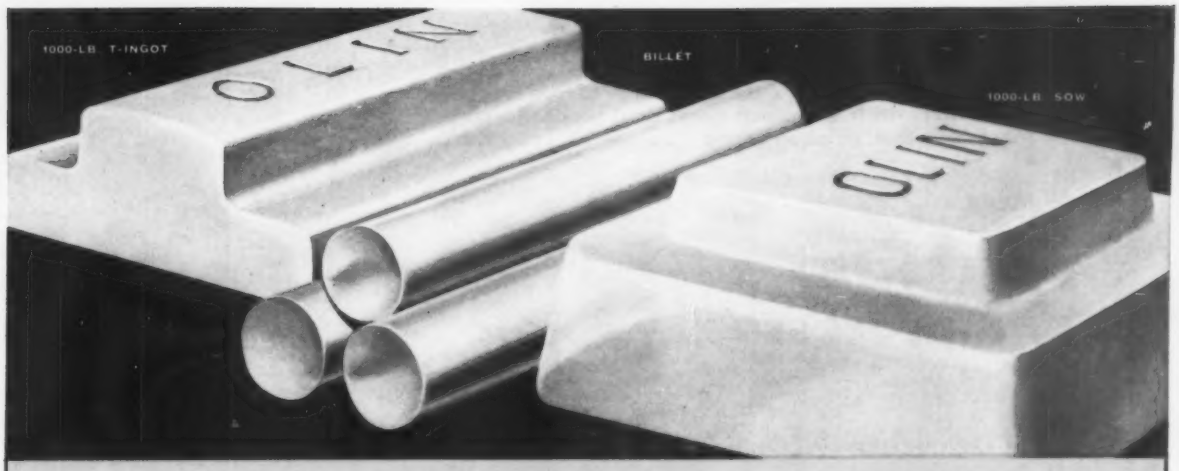
This handbook integrates the experience acquired throughout industry to date in selecting, applying and interpreting tests designed to improve performance reliability of equipment, to cut costs, to insure product quality or uniformity, to increase the utilization of materials and reduce breakdowns and accidents.

Tool Engineers Handbook, 2d Edition . . . 2289 pp. American Society of Tool Engineers, 10700 Puritan, Detroit. 1959.

With the aid of 1709 illustrations and 605 tables the book covers the latest in tool design, fabrication, maintenance and utilization.

Zinc—The Science and Technology of the Metal, its Alloys and Compounds . . . 700 pp. Reinhold Publishing Corp., 430 Park Ave., New York. 1959.

The book's 14 chapters cover such topics as economics, geology, ore treatment, refining, processing, alloy technology, zinc compounds and the many uses for zinc.



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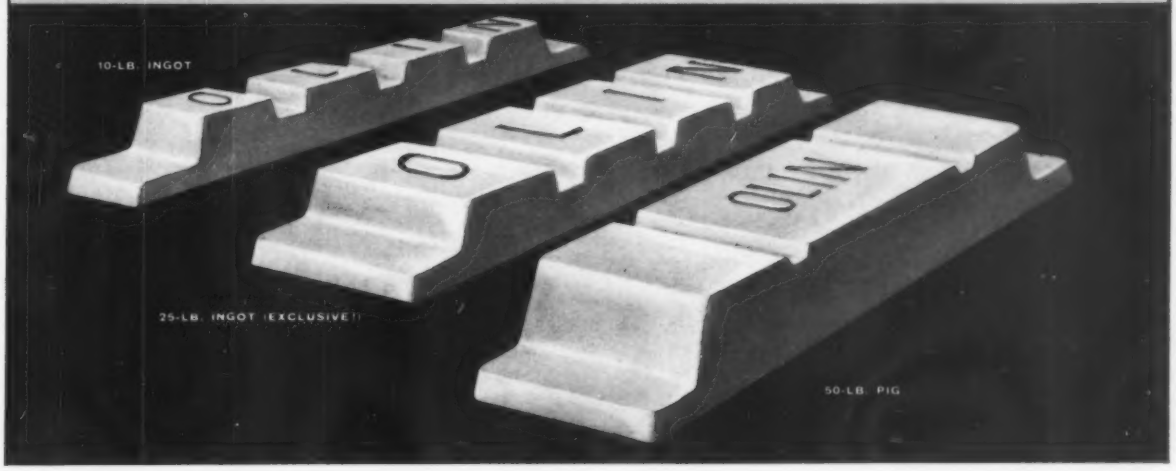
OLIN ALUMINUM PIG, INGOT AND BILLET



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FOR FOUNDRIES

Alloy pig and ingot, in standard alloys, in 10, 25 and 50 lb. sizes. (10 and 25 pounders offer exclusive benefits: smaller size to increase handling efficiency and speed melting; deep notches for easier breaking; 4-section design with smaller sections for faster crucible charging.)

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Pure pig, rotor ingot, custom alloys for special applications

You know what you're getting in Olin Aluminum. For this is primary metal—clean, uniform and with quality controlled by the most advanced techniques. So for dependable deliveries of pig, ingot or billet—call the Olin Aluminum Sales Office or distributor in your area.

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Circle No. 154, Page 13 or 145

Build an idea file for improvement and profit.
Circle numbers on literature request card (opposite page) for more information about these . . .

new products and processes

LOW THERMAL CONDUCTIVITY . . . light weight and increased mechanical strength in insulating fire brick allow it to be fitted with pins or hangers without danger of breakage. Resistant to direct flame exposure and withstands

erosive effects of circulating gases and flame impingment. Can be tailor-cut, drilled or shaped, eliminating need for special shapes. Babcock & Wilcox Co.
For More Information, Circle No. 1, Page 15

POWERED WHEELBARROW . . . 3/4-ton capacity, features quick interchangeability of dump bucket and flatbed platform for versatility. Powered

by 7-hp air-cooled engine, unit takes 20 per cent incline fully loaded. Less than 3 ft wide and 6 ft long. Prime-Mover Co.
For More Information, Circle No. 2, Page 15

ELECTRIC VIBRATORS . . . featuring water and dust-tight construction allow operation in constant exposure regardless of weather or media. Employs rotating eccentric shaft principle of vibration eliminating belts and pulleys. Cleveland Vibrator Co.
For More Information, Circle No. 3, Page 15

CO_2 GASSER . . . pressure gassing machine features 25 x 30-in. conveyorized table and cast spacers for quick vertical height adjustment, 20 x 24-in. gassing head and timing controls. Alphaco, Inc.
For More Information, Circle No. 4, Page 15

HEAT TREATING FURNACE . . . modified hearth-type construction for 2250-2400 F range, operates on available gas supply using venturi air mixer burner design. By firing across underside of silicon carbide hearth, flame

does not come in direct contact or impinge upon work. Available in four sizes as special sealed unit for most metal processing requiring atmosphere control. Charles A. Hones, Inc.
For More Information, Circle No. 5, Page 15

GLASS FOR METALCASTING . . . fused silica glass is new product recommended for: permanent molds, permanent back ups for shell molds, one-piece furnace hearths and crucibles for induction melting. Glasrock Corp.
For More Information, Circle No. 6, Page 15

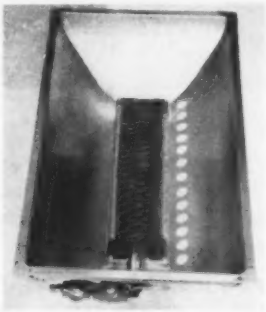
ALUMINUM ALLOY . . . with unusually high physicals is designed for sand and permanent mold castings for missiles and aircraft. Alloy MA-356 produces castings to exceed MIL-C-21180A. Rolle Mfg. Co.
For More Information, Circle No. 7, Page 15

DO-IT-YOURSELF SOLAR FURNACE . . . for budget-minded. Build 60-in. diameter size which creates temperatures to 6741 F in seconds. Furnace permits freedom from contamination, wide range

of ideal environmental conditions, observation and measurement at close range, heating and cooling test objects rapidly for thermal shock cycling. Also available as assembled. Waltham Precision Instrument Co.
For More Information, Circle No. 8, Page 15

OVEN LUBRICANT . . . said to have greatest heat, acid and pressure resistant qualities ever known in petroleum greases and oils. Withstands heat to 1900 F and remain impervious to acids. Does not react with ferrous metals. Lubrication Engineers, Inc.
For More Information, Circle No. 9, Page 15

INFRA-RED GENERATOR . . . operating on LP or natural gas has input of 24,000 btu, providing 70 F temperature in foundry bays. May be used in



tandem. Stresses safety features with shut-off valves, solenoids and regulators. Lambert Industries, Inc.
For More Information, Circle No. 10, Page 15

SHRINKAGE AND DRAFT CALCULATOR . . . plastic slide-chart provides time-saving method of determining draft and shrinkage. Kelm Mfg. Co.
For More Information, Circle No. 11, Page 15

CO_2 SHELL COAT . . . resin spray or dip for CO_2 cores provides strength, finish and improved collapsibility. Para Products Div.
For More Information, Circle No. 12, Page 15

OIL SAND BINDER . . . used with mineral oil and fine silica sand is said

to improve surface finish and cut surface imperfections, particularly in nonferrous metals. Sand is almost 100 per cent re-usable and mulled in 3 to 5 min. Minerals & Chemical Corp. of America.
For More Information, Circle No. 13, Page 15

CATALYTIC EXHAUST MUFFLERS . . . for LP-operated fork lift truck, cuts carbon monoxide fumes 98 per cent in Gary, Ind., plant. Purifiers channel hot exhaust fumes through catalytic agent promoting oxidation reaction changing incompletely burned contaminants to carbon dioxide and water vapor. Oxy-Catalyst, Inc.
For More Information, Circle No. 14, Page 15

PORTABLE SAND BLASTER . . . uses all types of abrasives with three sizes of job-suited nozzles. Requires no set-up time and may be used in small area

with cardboard box or cloth shielding. Trigger-type gun allows one-hand blasting control. ALC Co.
For More Information, Circle No. 15, Page 15

MAKE YOUR OWN . . . V-belts with new kits that contain rolls of belt and handy alligator fasteners. Saves valuable down-time when belts need replacing. Flexible Steel Lacing Co.
For More Information, Circle No. 16, Page 15

NO OPERATING COST . . . no maintenance when using new permanent ceramic magnetic pulley for fast continuous removal of tramp iron from foundry sand. Dings Magnetic Separator Co.
For More Information, Circle No. 17, Page 15

CHEMICALLY CLEAN AND SHARPEN . . . dull, clogged, metal-working files by immersion in liquid. Said to double and triple file life. Kendall Laboratories.
For More Information, Circle No. 18, Page 15

VACUUM CUP . . . lift truck attachment permits handling of cartoned material without need for clamps or forks. The Yale & Towne Mfg. Co.
For More Information, Circle No. 19, Page 15

HIGH TEMPERATURE LUBRICANT . . . has ability to resist settling, combined with ability to lubricate at temperature above point where most petroleum oils carbonate. Recommended for

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9	21	33	45	57	69	81	93	105	117	129	141	153	165	177	189	201	213	225
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4	16	28	40	52	64	76	88	100	112	124	136	148	160	172	184	196	208	220
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6	18	30	42	54	66	78	90	102	114	126	138	150	162	174	186	198	210	222
7	19	31	43	55	67	79	91	103	115	127	139	151	163	175	187	199	211	223
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11	23	35	47	59	71	83	95	107	119	131	143	155	167	179	191	203	215	227
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oven conveyors, kiln cars, gears and bearings. Acheson Colloids Co.
For More Information, Circle No. 36, Page 18

WET BLASTING ABRASIVE . . . consisting primarily of glass beads, features good cleaning properties and low metal removal in wet blasting of ferrous and non-ferrous parts. Resistant to fingerprinting on non-ferrous parts and water staining in drying. Abrasive has average life of 40-50 hr of actual blast time. Techline Div., Wheelabrator Corp.
For More Information, Circle No. 21, Page 18

ALUMINA RAMMING MIX . . . in plastic or dry premix, is said to have extremely high strength after drying. Applications include furnace hearths, roofs, sidewalls and burner ports; ladles, mixers and spouts; and ferrous, nonferrous and electric melting furnaces. Can be laminated to spalled fire brick and other refractories with rough surfaces. Ramtite Div., S. Obermayer Co.
For More Information, Circle No. 22, Page 18

ADJUSTABLE VIBRATOR . . . has variable impact range for producing straight line vibration in any direction. Provides continuous flow of bulk materials in foundry without sticking, arching or bridging. The Wellman Co.
For More Information, Circle No. 23, Page 18

CORE ROLLOVER DRAW MACHINES . . . automatic and semi-automatic-capacities from 500-1000 lb. Said by manufacturer to feature improved rollover action with 7-10 sec over-all cycle; simplified control circuit using fewer valves and single push button operation; more rugged construction; improved cushioning. Beardsley & Piper Div., Pettibone Mulliken Corp.
For More Information, Circle No. 24, Page 18

AUTOMATIC AIR POLLUTION MONITOR . . . checks amount of toxic materials in air with process taking 70 sec. If total amount is in critical zone, warning horn sounds and red light goes on. National Spectrographic Laboratories, Inc.
For More Information, Circle No. 25, Page 18

IMPACT TESTER . . . power-operated, remote-controlled, performs izod, charpy and tension-impact tests for metals. Said by manufacturer to feature new safety and mechanical features. Testing Machines, Inc.
For More Information, Circle No. 26, Page 18

FURNACE . . . for firing shell investment molds features heating chamber with trap doors for molten wax to drop through into water bath. Alexander Saunders & Co.
For More Information, Circle No. 27, Page 18

PLATFORM TRUCK . . . is powered by 9.2 hp air-cooled engine and hauls 1000 lb of freight or personnel on 18 sq ft deck. The Prime-Mover Co.
For More Information, Circle No. 28, Page 18

TRAVEL IN ANY DIRECTION . . . with new "Crab" truck that traverses in

Continued on page 18

PAYLOADER® is more productive

because it's more maneuverable

Never before has so much carry capacity, ease of operation and short-turning ability been combined in a tractor-shovel. That is why the model H-25 "PAYLOADER" is setting new tonnage records on boxcar unloading and other close-quarter work. "No machine you can put in a boxcar is as good as a HOUGH," says Bob Freun of Fruen Fertilizer, Hatfield, Minn.

It digs and carries 2,500 lbs. low and close with good balance and fullest operator visibility. Power-steering and only 6-foot turning radius, power-shift transmission with torque-converter drive, and powerful hydraulic brakes all assure the operator of safe, easy and accurate control. He can maneuver around corners, through narrow aisles, doorways and crowded yards, up and down ramps with speed and safety.

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These features give low-cost bulk handling

2,500 lbs. carry capacity • Only 6-foot turning radius • Power-shift transmission • Power steering • Power-transfer differential • 40° bucket tipback at ground • 4,500 lb. bucket breakout force • Fullest mechanical protection • Useful extra attachments

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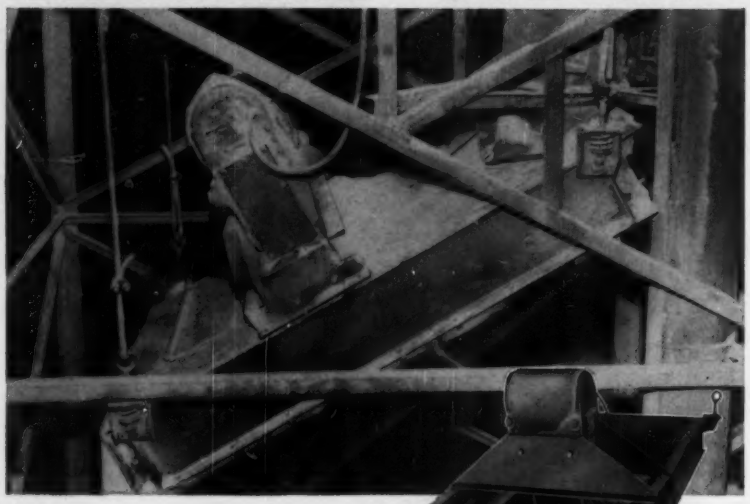
Circle No. 156, Page 15 or 145

SYNTRON

VIBRATING SCREENS



provide efficient, dependable low cost screening and reclaiming of foundry sand

SYNTRON designs and builds a screen for every foundry need—conditioning and reclaiming foundry sand, conveying and shakeout of castings, and screening and conveying sand and scalped materials.

SYNTRON Vibrating Screens are available in a variety of styles and sizes for every screening application.

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HOPPER LEVEL SWITCHES

DRY FEEDER MACHINES

COUNTER BALANCED CONVEYOR SCREENS

Circle No. 157, Page 15 or 145

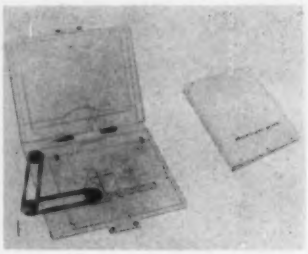
products and processes

Continued from page 16

any direction or angle with any shaped load. Said to be easier to steer in tight aisles and around corners. Will right-angle stack. The Yale & Towne Mfg. Co.

For More Information, Circle No. 29, Page 15

LIGHT WEIGHT DRAFTING SET . . . brief case design, allows accurate engineering sketches while on the job, en-route or at home. Has built-in drafting



machine, holemeter, protractor and vertical and horizontal scales. Also has 8 deg inclined drawing surface. Charles W. Thrift Co.

For More Information, Circle No. 30, Page 15

RADIANT HEATER . . . reaches full heating capacity of 800-850 F within 3 min, eliminating costly warm-up delays and need for complex equipment to divert heat after shut-down of line. Designed for horizontal mounting. High-watt density heater produces average of 20 watts per sq in. of working surface. Emits long wave infra-red rays from wire coils enclosed in 96 per cent silica glass. Corning Glass Works.

For More Information, Circle No. 31, Page 15

NON-ELECTRIC FIRE ALARM . . . heat-sensitive and self-contained, has visual glass eye monitor and indicating liquid level. When temperature reaches unit's operating point, pressure release

activates horn signal which lasts 15-20 min with 3/4-mile outside range. Only unit in danger area operates, others are not affected. Unit guards 400 sq ft space. Standard Fire Alarm & Signal, Inc.

For More Information, Circle No. 32, Page 15

PROVEN PRODUCTS FOR THE FOUNDRY INDUSTRY

RCI
Creative Chemistry
...Your Partner in Progress

Self-Curing Oil Binders;
Sand Conditioners;
Phenolic Shell Molding Resins;
Phenolic, Amino and
Alkyd Core Binders

When close tolerances are vital

RCI FOUNDREZ INSURES ACCURACY IN HICA SHELL MOLDING PROCESS

Shreveport, La. —HICA, INC., reports that shell molds made with Reichhold's FOUNDREZ 7504 powdered phenolic resin produce "High Integrity CAstings" for manufacturers of chemical and milk processing equipment, aircraft, missile, pump, valve and burner parts. HICA pours stainless and other alloys on intricate jobs requiring extremely close tolerances.

HIGHEST DEPENDABILITY

In a recent interview Phillip R. Johnson, HICA shell molding foreman, said "The dependability of RCI's FOUNDREZ recently helped us supply a large order of complicated castings without a single reject by our customer. With FOUNDREZ, we are able to avoid the warpage and cracking frequently encountered with other resins. Nor have we experienced any problem that could be attributed to our use of FOUNDREZ."

HICA *team ready to close cope and drag halves of plug valve handle adapter mold after cores have been set in place.*

HICA'S *shell molding department. Up-to-date methods and machines help produce accurate, economical castings.*

ECONOMY IMPORTANT

Besides dependability and quality, economy played a significant part in HICA'S choice of FOUNDREZ. "The superior bonding qualities of RCI's FOUNDREZ 7504," said Mr. Johnson, "allow us to use less resin per pound of sand, affording us substantial savings in our production run. It's easy to see why we use FOUNDREZ exclusively in all our shell molding techniques."

VARIETY OF RESINS

Reichhold's FOUNDREZ 7500 series of powdered phenol-formaldehyde resins, designed especially for shell molding, includes:

FOUNDREZ 7500 — a general purpose phenol-formaldehyde resin. Features long flow and cure. This product is especially applicable to intricate-pattern work.

FOUNDREZ 7504 — formulated for intermediate flow and long cure properties. Ideal for the jobbing shop where many different types of castings are made. May be employed on a variety of pattern contours.

FOUNDREZ 7506— has the shortest flow and fastest cure of the series. Compounded for high speed production of shells. Most suitable where foundry production involves long runs of a few types of castings.

If you would like further information on the FOUNDREZ 7500 series, write for Technical Bulletin F-3-R. Reichhold Chemicals, Inc., RCI Building, White Plains, New York.

Circle No. 158, Page 15 or 145

Make sure of your melts with

Nickel for general alloying

High-purity Electrolytic Nickel for ferrous and non-ferrous alloying. Inco Nickel cathodes are one of the purest commercial forms of Nickel . . . economical, too. For charging into most common furnaces such as electric, cupola, open hearth.

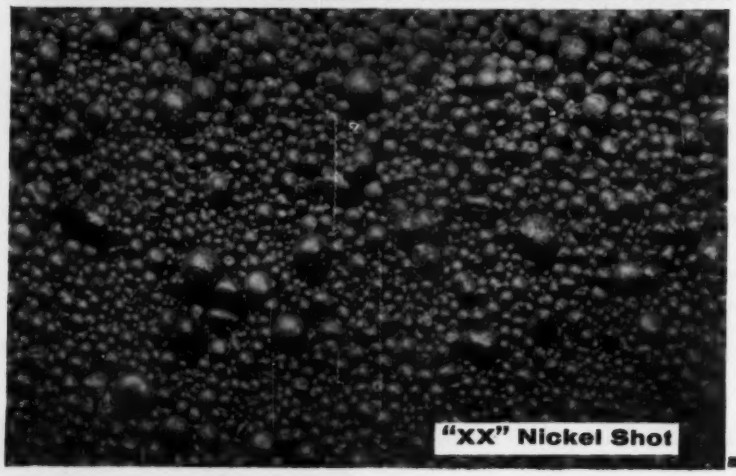
Available in sizes to fit your needs—full size and cut cathodes; various standard electrolytic nickel squares; "QM" Quick-Melting electrolytic nickel squares for non-ferrous alloying.

Nominal composition

Nickel (including cobalt)	99.95%
Iron	.01-.04
Copper	.01-.03

Fully complies with requirements of A.S.T.M. Designation B 39-22.

Sizes available	Approx. size, in.	Packaging	Approx. wt., lbs.
Full size cathode	(38x28½x⅜)	Skid pallets or loose.	145
Cut cathode sizes	(12x28½x⅜)	2000-4000 lb. skid pallets and skid boxes; also loose in carloads or truckloads.	45
	(9x28½x⅜)		36
	(4½x28½x⅜)		18
Standard nickel squares	(9x9x⅜)	In steel drums 500-725 lb.; also in 3000-4000 lb. skid boxes.	12
	(4x4x⅜)		2½
	(2x2x⅜)		–
	(1x1x⅜)		–
"QM" Quick Melting nickel squares	(1x1x⅛)	In steel drums 425 lb.	–



High-purity "XX"* Nickel Shot for alloying with iron and steel at spout or ladle. It is produced by pouring molten electrolytic nickel into a water bath. Standard sizing is obtained by screening through a one-inch opening and remaining on an .053-inch opening. Packed in 475 lb. drums.

Nominal composition

Nickel (including cobalt)	99.60%
Iron	.15
Silicon	.10
Carbon	.10

Get prompt technical information as well as immediate delivery by calling your local Inco foundry products distributor. Or write Inco directly . . . ask for "Commercial Forms of Inco Nickel", "Inco's Additives for Ductile Iron", and "Nisiloy for Gray Iron Castings." To find out how Nickel improves the properties of iron, steel, and non-ferrous castings, send for "A Quick Guide to the Nickel-Containing Casting Alloys."

*Trademark of International Nickel Company, Inc. • **The INTERNATIONAL NICKEL COMPANY, Inc.** • 67 Wall Street, New York 5, N. Y.

high-purity Inco Nickel products

Nickel alloys for iron melts

High-purity "F"* Nickel Shot and Ingots for addition to gray irons. Shot melts at 2300° F for quick solution in molten iron. Sized between .25" and .0193" for easy addition at ladle or spout. Packed in 500 lb. drums. Ingots, about 5 lb. each for convenience in direct cupola charging, are also packed in approximately 500 lb. drums.

Nominal composition

Nickel (including cobalt)	92.00%
Silicon	5.50
Iron	1.65
Carbon	.55
Copper	.20

Nisiloy* Nickel-Silicon Inoculant for improving machinability in gray irons. The only inoculant improving *both* machinability and tensile strength. "Nisiloy" inoculant also improves uniformity and fineness of graphite distribution, wear resistance and toughness, while reducing chill and casting defects. Melts at 1800° F, diffuses rapidly. Supplied in granules sized ¾" to 20 mesh. Packed in 500 lb. drums.

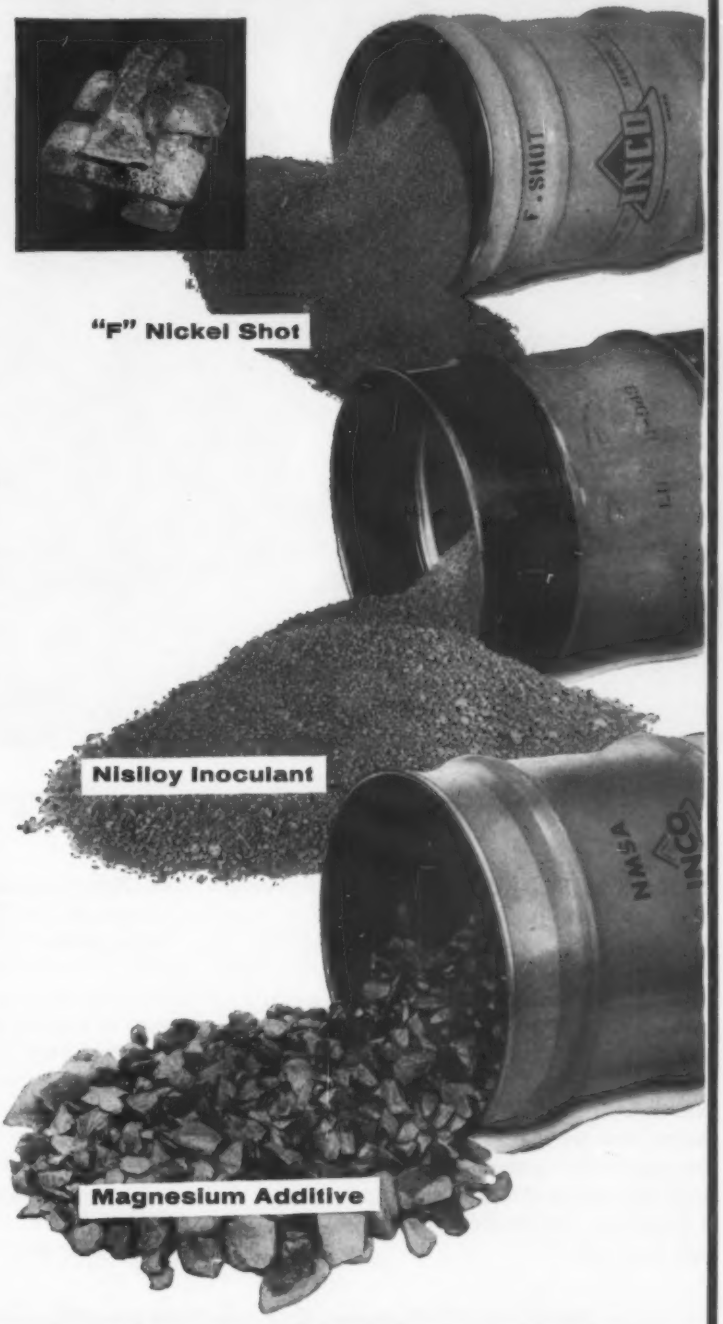
Nominal composition

Nickel	59.00%
Silicon	29.00
Iron	balance

Magnesium Additives – NMA #1* and NMSA #2* for obtaining desired properties in both regular and austenitic ductile irons. Useable with all types of melting units, with all methods of ductile iron production. Supplied in 2 sizes –2¼" x ¾" and 1" x 8" mesh.

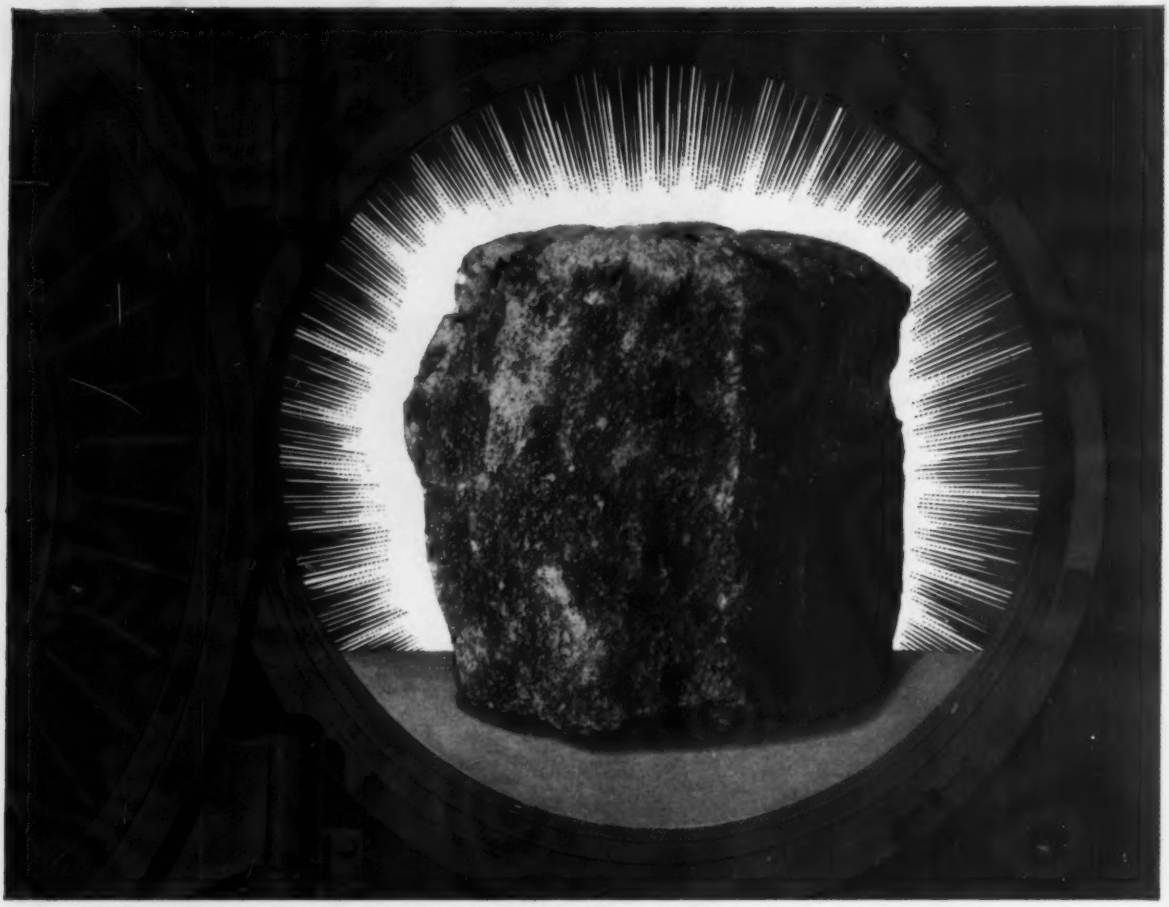
NMA #1 Additive for high strength ductile iron. Provides most efficient magnesium recovery. Compared to other commercial additives, it has good response to heat treatment. Packed in 500 lb. drums. **Nominal composition:** 15% magnesium, balance Nickel.

NMSA #2 Additive for toughness, ductility. Efficient in magnesium recovery. Has fair response to heat treatment. Packed in 400 lb. drums. **Nominal composition:** 15% magnesium, 30% silicon, balance Nickel.



INCO NICKEL

NICKEL MAKES CASTINGS PERFORM BETTER LONGER



Valuable asset: ADAPTABILITY

ADAPTABILITY to individual cupola and melting requirements is one of the most valuable assets you can have in the coke you use.

When you specify Semet-Solvay foundry coke, you have a choice of *five* different sizes—offering maximum adaptability to your melting practice. And whichever size you choose, you are always sure of getting carefully screened, uniformly sized coke that is sturdy and blocky in structure, consistent in analysis, high in carbon.

Buying coke from Semet-Solvay offers you other advantages, too: Four strategically located plants for fast, dependable service . . . coke that is quality-controlled from mine to cupola . . . services of metallurgical experts to assist on foundry problems.

If you are not already a user of Semet-Solvay foundry coke, why not find out right away how it can help you realize a hotter, cleaner, faster cupola operation? Just contact your nearest Semet-Solvay office or write directly to us for complete details.

The "Solvay"—"flagship" of Semet-Solvay's fleet of diesel boats and coal barges that move coal by water routes from our mines to our coke plants.

Yours for better melting...

SEMET-SOLVAY DIVISION

Dept. 557-BI, 40 Rector Street, New York 6, N.Y.

BUFFALO · CINCINNATI · CLEVELAND · DETROIT

IN CANADA: ALLIED CHEMICAL CANADA, LTD., SEMET-SOLVAY DEPT., TORONTO

WESTERN DISTRIBUTOR: WILSON & GEO. MEYER & CO., SAN FRANCISCO · LOS ANGELES

Allied Chemical

Circle No. 139, Page 15 or 145

A Timely Message for Foundry Managements

IMPROVED PROFIT MARGINS

Out-of-date or improperly administered incentive wage payment plans reduce productivity and increase costs. Knight Engineers can assist you to establish standards which will reflect the work content of the job . . . and have resulted in direct labor cost reductions up to 50%.

These same standards may be used for

Estimating and quotations
Incentive wage payment plans
Labor and cost controls
Flexible budgets
Scheduling and production control

Knight experience is readily available to assist you to plan your profit margins.

KNIGHT SERVICES INCLUDE:

Foundry Engineering • Architectural Engineering • Construction Management • Organization Management • Industrial Engineering • Wage Incentives • Cost Control • Standard Costs Flexible Budgeting • Production Control • Modernization • Mechanization • Methods Materials Handling • Automation • Survey of Facilities • Marketing

Lester B. Knight & Associates, Inc.

Management, Industrial and Plant Engineers

Member of the Association of Consulting Management Engineers, Inc.

549 W. Randolph St., Chicago 6, Ill.

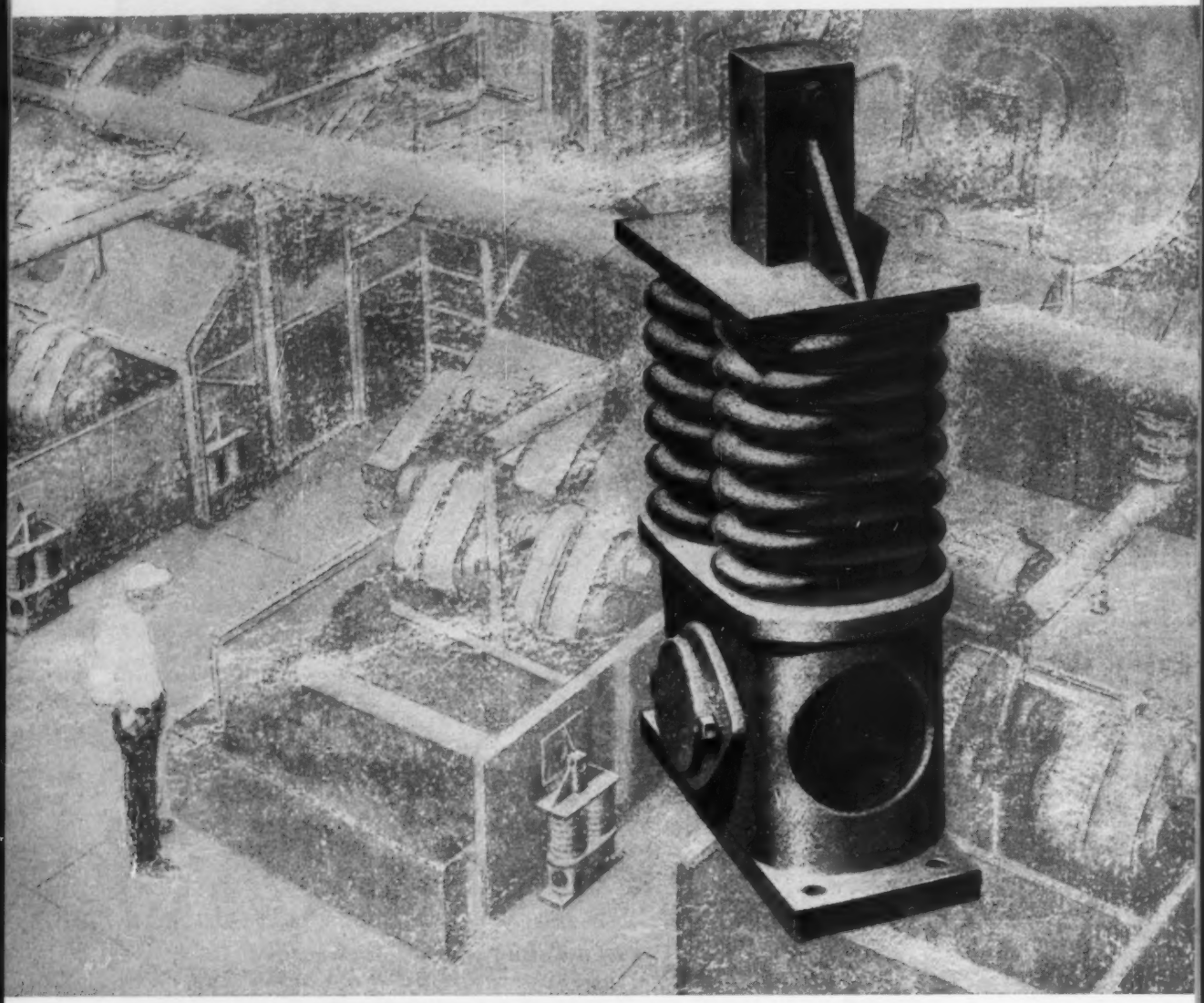
New York Office—Lester B. Knight & Associates, Inc., Management Consultants, 500 Fifth Ave., New York 36

Knight Engineering Establishment (Vaduz), Zurich Branch, Bahnhofstrasse 17, Zurich, Switzerland

Lester B. Knight & Associates, G.M.B.H., Berliner Allee 47, Düsseldorf, Germany

Circle No. 160, Page 15 or 145

How the Foundry Industry Serves America . . . #4 of a Series



CAST IRON SPRING BASES IMPROVE PERFORMANCE, CUT MACHINING TIME 30%

When the spring bases of this big vibrating screen were redesigned from plate weldments to gray iron castings, it effected not only a substantial cost saving, but also provided maximum stability to the structure.

The excellent compressive strength and damping characteristics which are inherent in gray cast iron combine to make it an ideal material for this particular application, namely, a sturdy dependable supporting part for a structural or machine unit.

Modern foundries look to the Hanna Furnace Corporation for their supplies of all regular grades of pig iron . . . foundry, malleable, Bessemer, intermediate low phosphorus as well as HANNATITE® and Hanna Silvery.

Facts from files of Gray Iron Founders' Society

HANNA
THE BEST KNOWN NAME IN IRON

THE HANNA FURNACE CORPORATION
Buffalo • Detroit • New York • Philadelphia
Merchant Pig Iron Division of
NATIONAL STEEL CORPORATION

Circle No. 161, Page 13 or 145

In the interest of the American foundry industry, this ad (see opposite page) will also appear in

STEEL
IRON AGE
FOUNDRY
AMERICAN METAL MARKET

FREE!

REPRINTS OF THIS AD WITH YOUR FIRM'S SIGNATURE

If you would like to have reprints of this ad to mail to your customers and prospects, let us know. Reprints will have no Hanna product message or signature, but will be imprinted with your firm name and address. Absolutely no obligation. To order your reprints, fill in and mail the coupon below.

The Hanna Furnace Corporation
Detroit 29, Michigan

Please send me_____reprints of Ad No. (No.)
____of your Foundry Industry Series.
Imprint as follows:

_____
_____
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Send reprints to:

NAME_____

I understand there is no charge for this service.

Circle No. 162, Page 15 or 145

pouring off the heat

comments on depreciation

■ I have just completed reading the article entitled, "Tax Consultant Talks to a Foundry Operator About Depreciation," appearing in the August issue of MODERN CASTINGS. The article very clearly points out, especially to others than accountants, the methods available to set up depreciation records. And it clearly illustrates the necessity of using depreciation records for other purposes than to just recover cash outlays.

This article should be of value to all foundrymen.

W. D. Dunn
Oberdorfer Foundries, Inc.
Syracuse, N. Y.

■ We were very interested in the article entitled, "Tax Consultant Talks to a Foundry Operator About Depreciation," which appeared in your August issue of MODERN CASTINGS.

"Depreciation" is a term that has puzzled many businessmen. The way the Tax Consultant explains the meaning of the word and the importance of its application in business practice is very good.

In the continual rising cost of foundry equipment, depreciation is one of the items that must be included in our cost. In fact, the Government has not allowed as much depreciation as we should have in foundry operations. Equipment in the foundry has particularly hard wear and faster obsolescence than in many other industries. If foundries want to stay competitive they will have to keep re-equipping with equipment that costs more than the original installation.

Because of its importance we should all have a clear understanding of what depreciation means and how. If we don't follow it properly, depreciation can put us in the sheriff's hands.

Walter L. Seelbach
Superior Foundry, Inc.
Cleveland

■ After reading your MODERN CASTINGS article concerning depreciation, I felt like adding a few comments of my own. So here they are.

In my estimation no method of charging off depreciation adequately provides for the full cost of replacement. This means that our profits, however thin, are always seriously overstated.

Irv, the C.P.A. in the story, could well have emphasized this point as it is frequently overlooked. Costs of new equipment are always considerably higher than the total write-off of the old. And I suspect that will always be the case. It behooves all of us, therefore, to regard our profits as overstated. We pay income tax on earnings that are actually fictitious!

Allen M. Slichter
Pelton Steel Casting Co.
Milwaukee

■ While on my way to the Penn State Foundry Conference I had the opportunity of exploring this old charcoal iron

furnace. Thought some of the MODERN CASTINGS readers might like to reminisce about the good old days.

O. Jay Myers
Reichhold Chemicals, Inc.
White Plains, N. Y.

red alert

■ I would like to object to a prominent statement made on your editorial page in the August issue.

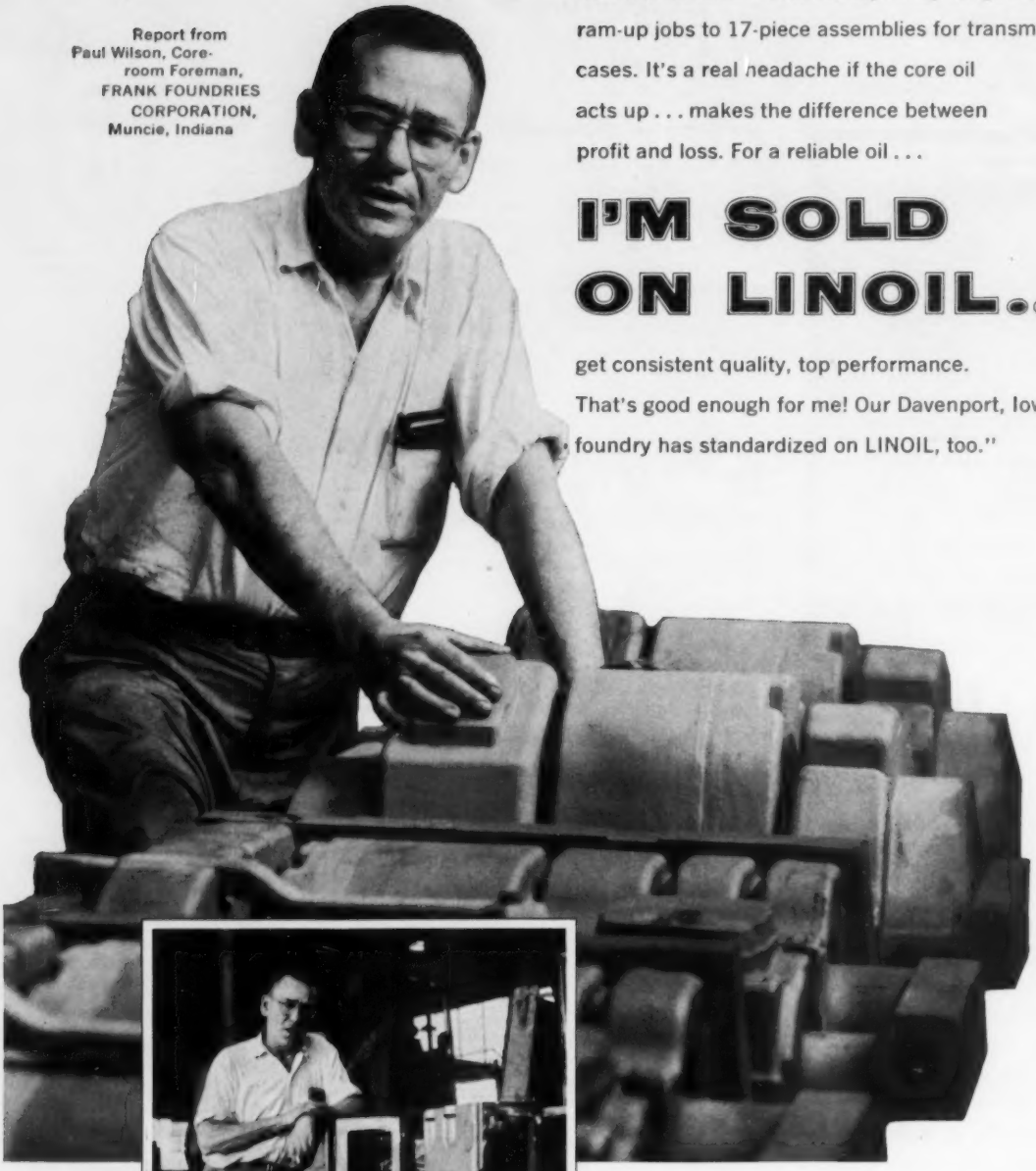
> *"Magnesium can be cast in plaster molds, but just be sure you have at least 3 per cent potassium fluoborate and sulphur in the mix to inhibit the violent Mg-H_2O reaction."*

If some foundryman who has hesitated to cast magnesium alloy in plaster molds decides to try it on the basis of this information, there may be a repetition of an incident that occurred a few years ago in Tulsa. An inexperienced group poured a 40-lb magnesium casting in a plaster mold and burned down a foundry.

If a foamed plaster mold is made from a mixture containing about 1-1/2 per cent sulphur and 1/2 per cent KBF_4, and if the mold part is processed in an oven long enough so that the center of the heaviest section is above 220 F, then it is probable that magnesium alloy can be poured into the mold without reaction.

Magnesium alloy castings are being made to a limited extent in plaster molds, but it is not a simple process. In any case, it would be well to do the development work with small castings.

M. E. BROOKS
The Dow Chemical Co.
Bay City, Mich.



Report from
Paul Wilson, Core-
room Foreman,
FRANK FOUNDRIES
CORPORATION,
Muncie, Indiana

"I run the core room in the Muncie foundry . . . turn out 60 tons of cores a day. They range from little ram-up jobs to 17-piece assemblies for transmission cases. It's a real headache if the core oil acts up . . . makes the difference between profit and loss. For a reliable oil . . .

I'M SOLD ON LINOIL...

get consistent quality, top performance. That's good enough for me! Our Davenport, Iowa, foundry has standardized on LINOIL, too."

"We can't risk quality on these costly transmission housings. Notice the intricate core work inside . . . reason enough to be fussy about my core oil."

Archer QUALITY

Archer-Daniels-Midland company

FEDERAL FOUNDRY SUPPLY DIVISION • 2191 West 110th Street • Cleveland 2, Ohio

Circle No. 163, Page 15 or 145

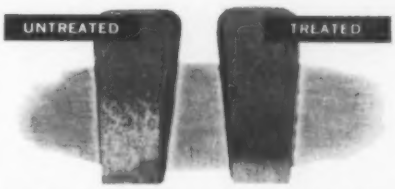
"No machining complaints since I used SMZ alloy"

You can eliminate chilled corners and hard spots in gray iron castings with ladle additions of "SMZ" alloy. Machining rates can thus be improved by as much as 25 per cent, giving you more satisfied customers.

"SMZ" alloy is the most widely used inoculant in the iron foundry industry. As little as 2 to 4 pounds of "SMZ" alloy per ton of iron are sufficient to eliminate chill in light castings. For harder irons of lower carbon and silicon contents, a larger addition of the alloy may be required.

For information on how "SMZ" alloy can improve the machineability of your castings, contact your UNION CARBIDE METALS representative. Ask for the booklet, "SMZ Alloy – An Inoculant for Cast Iron."

UNION CARBIDE METALS COMPANY, Division of Union Carbide Corporation, 30 East 42nd Street, New York 17, N. Y.



These chill blocks show how "SMZ" alloy reduced chill in a 3.15% carbon, 1.80% silicon iron.

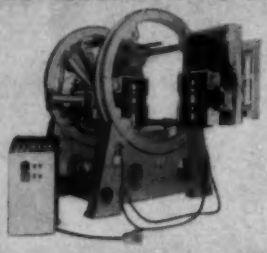
UNION CARBIDE METALS

Electromet *Brand Ferroalloys and other Metallurgical Products*

The terms "Electromet," "SMZ," and "Union Carbide" are registered trade-marks of Union Carbide Corporation.

Circle No. 164, Page 15 or 145

The Shalco Corporation, pioneers in Shell Core Blowers and Shell Molding Machines, joins forces and becomes a Division of the National Acme Company, pioneers in automatic multiple-spindle bar and chucking machines



NAMCO

The National Acme Company

EXECUTIVE OFFICES: 170 EAST 131st STREET, CLEVELAND 8, OHIO • GLENVILLE 1-9080

To The Foundry Industry:

Our "Zone of Responsibility" to the metalworking industry is constantly being broadened to include almost every production step from raw material to the finished product. In joining forces with National Acme, Shalco's exclusive developments and broad experience in the art of shell molding is combined with 75 years' experience in automatic machine tool manufacturing and servicing. The result is shell molding equipment built to the highest standards of machine tool precision and reliability.

Shalco's unique design and manufacturing techniques have resulted in low cost, greatly simplified Shell Core Blowers and Shell Molding Machines with unusual flexibility. We believe this outstanding equipment will now allow the Foundry Industry to take greater advantage of the economy, precision and high quality realized with shell molded castings.

One of the most complete engineering and application services in the industry is available to assist foundrymen everywhere in obtaining optimum results from this outstanding process.

T. L. Stimpert

President
The National Acme Company

How American Brake Shoe Maximates Production

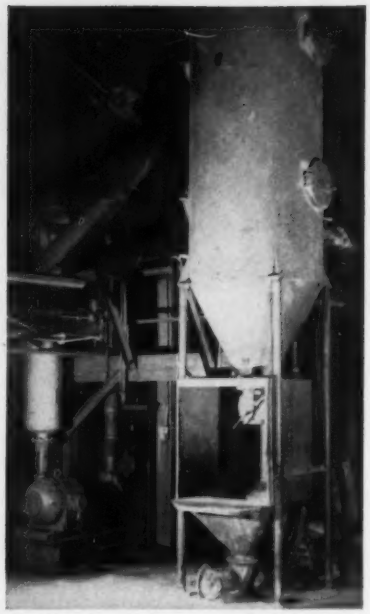
When the American Brake Shoe Company began an extensive modernization program at its New Castle, Delaware plant, one of the first steps management took to maximate production—that is achieve maximum output at less cost—was to install a Hoffman pneumatic conveying system for keeping bentonite, dextrin, silica flour and other materials *on the flow*. With a Hoffman exhauster furnishing the air as well as suction for the handling system, and use of components described here, the equipment not only simplified bulk conveying chores but paid its way in a few months by providing substantial production, material and labor savings.

MATERIAL INTAKE VALVE

Materials are introduced into the air stream through a unique nonclogging intake valve attached to the bottom of a hopper and flow smoothly through pipe lines to any one of six primary cyclone storage tanks more than 350′ distant. Hoffman intake valves insure the uninterrupted flow of dry, powdery or granular materials through all types of vacuum conveying systems. Suitable for use with 2″ through 6″ pipelines, they are equipped with standard 8″ flanges and can be easily attached to bins, hoppers, or dust collectors. Connected equipment is protected from exposure to the full suction of the system by a separate air inlet. The material handling rate can be adjusted while air is flowing. Thorough mixing insures smooth transit.

HINGE VALVE

Self-cleaning Hoffman hinge-type discharge valves are designed for air-tight closure against a head of material. The one-piece valve body is cast of gray iron with its rubber-faced disc and seat completely inside the casing. Lever linkage permits operation by means of chain or cable from a remote station. Provision can also be made for air or hydraulic cylinder actuation of the valve.



A portion of the Hoffco-Veyor system installed at the American Brake Shoe Co. plant in New Castle, Delaware.

ROTARY VALVE

Chain driven rotary discharge valves of cast semi-steel construction feed the material in controlled quantities. Designed for interchangeability of various types of fabricated and cast rotors, valves are equipped with torque limiting drive sprockets for protection against jamming and overloading. Equalizing connections permit attachment of bleed lines to vacuum or pressure source. Inspection of the interior can be made through an access port without disassembly of the valve.

PERISTALTIC VALVE

Controlled expansion and contraction of rubber diaphragms permit discharge in measured quantities. Since there are no internal moving parts, even coarse abrasives can be handled with minimum wear. Sheet rubber diaphragms are easily replaced whenever necessary.

COMPETITIVE ADVANTAGES

In handling quantities of dry, free-flowing powdery and granular materials such as sand, shot, chemicals, etc., Hoffco-veyor systems and components speed production—provide many genuine benefits and advantages which are reflected in higher profit margins. These include:

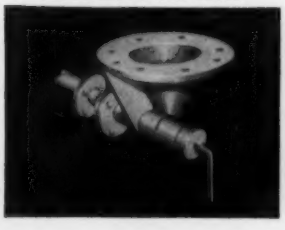
- flexibility
- cleanliness
- time saving
- lower initial cost
- easy installation
- material saving
- labor saving
- pay for themselves

FREE ENGINEERING SERVICE

If you have a materials handling problem, you can solve it with either a complete Hoffman system or any of its parts which may be purchased separately to fit your needs. Available equipment includes dependable centrifugal blowers/exhausters, cyclones, collectors, material intake, hinge, rotary, butterfly and peristaltic valves as well as filter bag collectors. We'll be glad to make a free engineering survey to determine how you can improve your manufacturing methods by maximating production with a really tight method of material handling. Send now for a free descriptive booklet. Please write:

Air Appliance Division
Dept. EM
U. S. Hoffman Machinery Corp.
103 Fourth Avenue
New York 3, New York

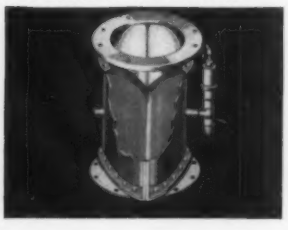
Material intake valve



Hinge valve

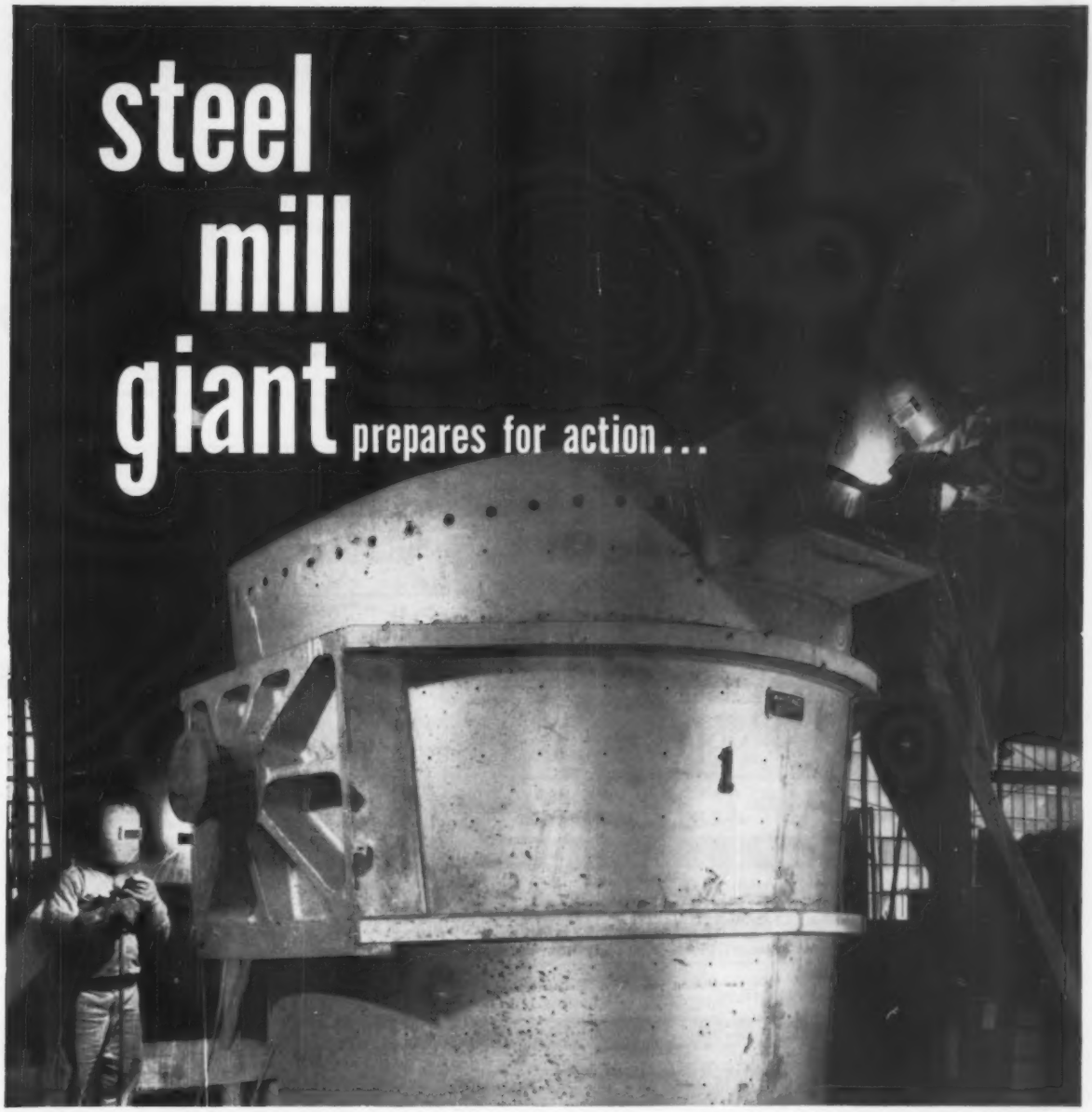
Rotary discharge valve

Peristaltic rubber valve



Circle No. 166, Page 15 or 145

steel mill giant prepares for action...



Preparations are nearly complete . . . and soon this giant 60-ton ladle, built to A.I.S.E. specs, will be pouring out profit for another satisfied Whiting customer. Cast steel trunion bases, forged steel trunions, and adjustable swivel-type bottom tapping lever guarantee low maintenance . . . easy control . . . long, rugged service life. When you need ladles—capacities from 100 lbs. to 200 tons—specify Whiting!

FREE CATALOG . . . Describes over 200 ladle types and sizes. Write today!
Whiting Corporation, 15628 Lathrop Avenue, Harvey, Illinois.

75th year

COST-SAVING EQUIPMENT . . . THE WAY TO HIGHER PROFITS

LADLES

WHITING

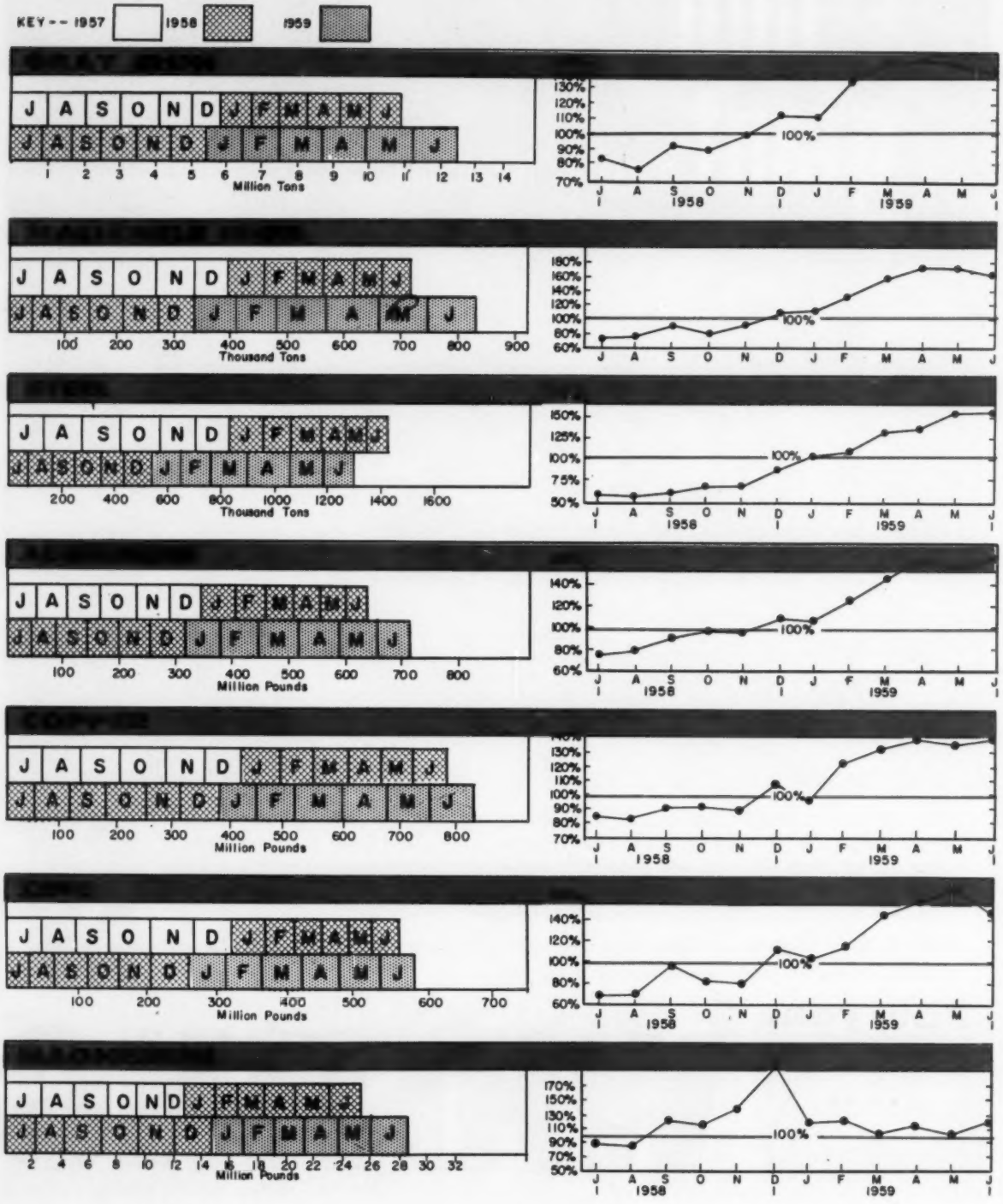
MANUFACTURERS OF CRANES; TRAMBEAM HANDLING SYSTEMS; TRACKMOBILES; FOUNDRY, RAILROAD, AND SWENSON CHEMICAL EQUIPMENT

Circle No. 167, Page 15 or 145

how's business . . .

Business in the metalcasting industry appears to be leveling off. By using statistics provided by the Bureau of Census, Department of Commerce, Modern Castings has prepared this special comparison of month-to-month metalcasting shipments for the years 1957, '58 and '59. On the left, horizontal bar charts give a direct comparison of each month for the two year period July 1957 through June 1959 and the accumulative total for the two years.

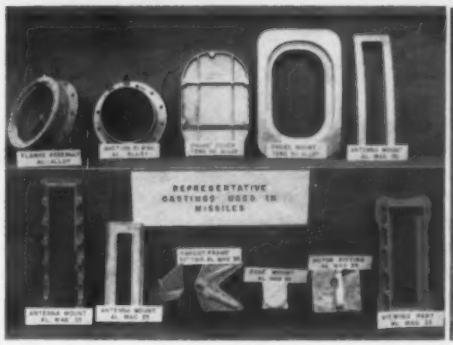
The right-hand set of graphs demonstrate the steady climb of business during the last half of 1958, continuing into 1959 and now beginning to level off. Shipments for each of the last 12 months are compared with the corresponding month a year previously and the ratio converted to per cent. For example, gray iron shipments were 954,102 tons in July 1957, and 791,560 tons in July, 1958—about 83 per cent of the 1957 rate. So the curve starts at 83 per cent for July, 1958, and climbs to 145 per cent for June, 1959 when shipments of 1,252,016 tons exceeded by far the 867,948 tons shipped in June, 1958.

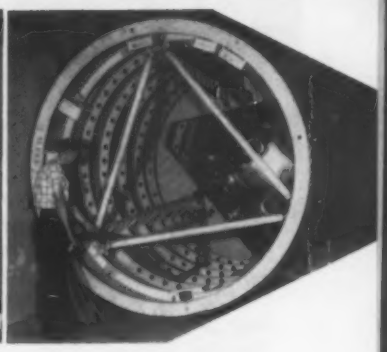


the editor's report

by Jack Salamon

■ **Here are some more high High Flying Castings . . .** in fact, these go out of this world. These aluminum castings are vital components of the Jupiter missile developed at the Redstone Arsenal in Huntsville, Ala. Engineers working for Von Braun, in an exclusive Modern Castings interview, expressed the opinion that: "Castings are best suited economically and time-wise for small orders necessary in research and development work. Castings are best suited for complex shapes too expensive to machine or too complex to forge. Redstone is getting castings cheaper and quicker than by other processes. In many instances casting has proved to be the only method suited to fabricating certain components."





■ **Early warning device . . .** to prevent furnace bottom damage. Texas Foundries, Lufkin, Texas, insert thermocouples in the firebrick lining on the bottom of air furnaces. A continuous thermal record then traces the progress of bottom burn-out. Temperature of bricks where thermocouple is located starts out reading about 1500 F. This reading gradually increases over a period of weeks. When couple reading gets up to 2100 F it indicates that only about three inches of bottom are left and it's time to reline. This beats waiting until the fateful day when the bottom floats up and all the metal in the furnace has to be pigged in a hurry!

■ **Want to cushion the shock . . .** of rolling over big drag molds? Use a large truck tire to absorb the strains.

■ **Hexachloroethane mold coating . . .** has spectacular effects on fluidity of aluminum—4.5 per cent copper alloy. Work at Massachusetts Institute of Technology by M. C. Flemings, H. F. Conrad and H. F. Taylor demonstrates that a coating of hexachloroethane, 0.006 in. thick, triples the fluidity of the aluminum alloy. Other aluminum alloys also show marked improvement in fluidty. The C_2Cl_6 is dissolved in ether and sprayed on the sand mold surface. Beneficial results apparently come from reduced surface tension or surface oxide films on the flowing metal.

■ **Safety measure . . .** at Ford Motor Co., Cleveland Foundry: All fork-lift trucks and front-end loaders must have their lights on when operating in the plant.

■ **1500 curies of Cobalt-60 . . .** a lot of radioactivity; in fact, the largest single isotope source in this country being used by a foundry for radiographing castings. This atomic camera is on location at Cooper Alloy Corp., Hillside, N. J., where it is used to guarantee quality of stainless steel castings—especially valves for AEC installations. A one hour exposure will penetrate 12 inches of steel!

■ **Casting sales engineers . . .** can save their customers a lot of money with a little upstream thinking. Look closely at the fabricating operations performed on your castings when they enter into your customer's manufacturing process. One observant Chicago foundry salesman saw how he could add cents to the cost of a casting and save dollars in the final cost of his customer's product. What did he do? On one job he introduced cast-in drill spots to eliminate need for starting drills and drill jigs. On another job he cast rivets onto doors and housings so only a hammer blow was needed to attach them to another part. Names cast into handles, doors, etc. eliminate nameplate expense. One-piece castings can often replace multiple welded-bolted assemblies. Keep castings out front with this added customer service.

NEW POLYMER SAND BINDER

by J. L. DEWEY *and* T. J. WEST
The Dow Chemical Co.
Western Division
Pittsburg, Calif.

A new sand binder with high conditioning action has recently become available to the foundry industry. It is a high molecular weight, water-soluble polymer that is an effective conditioner at low treatment levels of one to sixteen ounces per ton. Cereal may be eliminated from the sand mix when using this new sand additive.

The polymer improves all of the green sand properties, resulting in saving both sand and production costs. Flowability, with a typical sand, increases from 75 or less with cereal to 85 or higher. This increased flowability or rammability has a marked effect on green hardness. The mold hardness is increased from 75 to 80 in a conventional sand to 85 or higher with the polymer. Molds have a more uniform hardness in both the horizontal and vertical surfaces. In spite of the increased hardness and rammed density, the permeability is higher in most cases.

At first thought this is quite surprising but is a result of using ounces of the new agent instead of pounds of conventional binder. Conventional binders work through mass bonding. The large amounts required fill voids and decrease permeability. Green compressive strength is increased while green deformation is more uniform and does not show the wide variation obtained with cereal formulations. In Table 1 are presented typical results obtained in steel foundry sands using this agent as compared to cereal.

Tetrasodium pyrophosphate is sometimes used in conjunction with the polymer binder to improve the dry strength. In the case of some bentonites, the binder can be used alone. But with other bentonites a decrease in dry strength results. In such a case the addition of an equal amount of phosphate is necessary. The phosphate is used for a basic exchange of sodium cations for calcium cations and rejuvinates the bentonite. It also helps disperse the polymer and the bentonite more evenly throughout the sand.

A typical mix for a new sand facing uses 0.05 per cent polymer binder, 0.05 per cent sodium tetrapyrophosphate, 4-5 per cent western bentonite and 3-4 per cent moisture. From 0.2 to 0.8 per cent of a cushioning agent such as cob flour, grain husks or wood flour is used in some cases to help prevent expansion scabbing that might result from over ramming.

This material has now been well evaluated in commercial use in several steel foundries for over a year with excellent results.

A large north-central states steel foundry has been using two ounces of the new sand binder in place of three or four pounds of cereal in an all-purpose molding sand with considerable success. After several days of operation with this material the mold production had increased ten per cent. Ten molders were producing as many molds as eleven had made in the past. This was accomplished by the improved flowability of the sand, resulting in a reduction in riddling and hand ramming.

"PROOF of PRODUC

These steel castings demonstrate the smooth surface and sharp letter detail possible with new sand mix.

A noticeable improvement occurred in the pneumatic sand transport and slinger operations. Stoppage difficulties previously encountered were eliminated. As a result of better collapsibility and shakeout a 75 per cent increase in sand recovery was obtained. The sand formerly was too hard and lumpy for good recovery. At the same time the improved sand peel gave cleaner castings with sharper eye appeal and a reduction in scrap.

In changing over to the new sand binder, this foundry made no changes in their normal mulling practice. The white powdered agent was added to the muller along with powdered tetrasodium pyrophosphate and bentonite and mulled briefly before adding water. This binder is compatible with residual cereal and dextrin in the sand and shows an immediate improvement when used. However, the maximum benefit is not obtained until the combustibles are reduced by burn out.

This foundry has found that the mere addition of water and remulling produces an excellent sand for backup and slinger use. Previously, the addition of 11 lb of bentonite and 2-1/2 lb of cereal per ton of sand had been necessary in the backup sand and 11 lb of bentonite, 14 lb fire clay and 5 lb of cereal had been used in the slinger sand.

The dry strength of these sand formulations is not as high as the conventional cereal sand, but it is adequate. A higher dry strength is obtainable by increasing the bentonite, fines, or a combination of both. Since the polymer binder increases the flowability, high dry strengths can be attained by such additions without impairing good flowability and permeability. Exercise caution, however, since dry strengths that are too high can cause hot casting cracks, expansion scabbing, poor collapsibility and unsatisfactory shakeout.

Although the sodium tetrapyrophosphate has some buffering action which tends to hold the pH constant at about 7.5 to 8.0, adjustment of pH is no longer necessary to prevent spoilage.

In accordance with good sand practice, bentonites that have a high calcium content or have been pep-

s in the CASTINGS"

by JACK H. SCHAUM/*Editor*

Crucible Steel Castings Co. in Milwaukee used new polymer binder in producing these steel castings.

■ One of the success stories with this new polymer additive can be found at Crucible Steel Castings Co., Milwaukee. A mere 51-gram pinch of the additive goes into each 1000-lb batch of sand in the muller —only about 0.021 per cent.

In return for this addition, Crucible Steel succeeded in eliminating two per cent cereal entirely from the mix and reduced water content from 3.4 per cent down to 2.9 per cent. Western bentonite content averages 4.5 per cent. Absence of cereal in mix precludes any need to add tetrasodium pyrophosphate for pH control. About 78,000 lb of carbon steel are poured into some 1500 green sand molds made with this mix each day.

Jack Baumgardner, quality control engineer, emphasized that "after 6-months' experience with this new sand ingredient we have found a number of benefits, such as:

"More flowability which yields higher mold hardness (80-83).

"Elimination of hand-ramming operations.

"Increased mold production rate of 10 to 14 per cent.

"A permeability increase of 10 per cent (to a value of 130) at same rammed density.

"Reduced combustibles in the sand mix leading to less gas evolution, elimination of ash build-up in the sand, and prevention of undesirable carbonaceous coating on sand grains.

"Reduction in cost of our sand mix.

"Thinner and more complete sand peel from hot castings.

"Fluffier sand which cools off quicker during the three cycles it makes each day in the foundry."

The sand system contains about 85 tons and recycles three times a day in five hundred 1000-lb batches. This captive batch of sand supplies the squeezer floor where steel castings weighing up to 250 lb are made. Piecework molders have upped productivity 10 to 14 per cent because now they need only to drop the sand onto the pattern from overhead hopper, jolt the molds, strike off and squeeze. Such time consuming operations as facing, hand tucking, hand ramming and peening have been completely eliminated.

A limited quantity of this special sand runs over to the slinger floor where it is used behind the facing sand for backup because of its high permeability and flowability. Sand lost from the system in this manner is replenished by cores used in squeezer molds.

Once again a new product has been tailored for the metalcasting industry with upstream thinking by imaginative research laboratory engineers and given industrial implementation by aggressive foundry technical know-how. ■ ■ ■

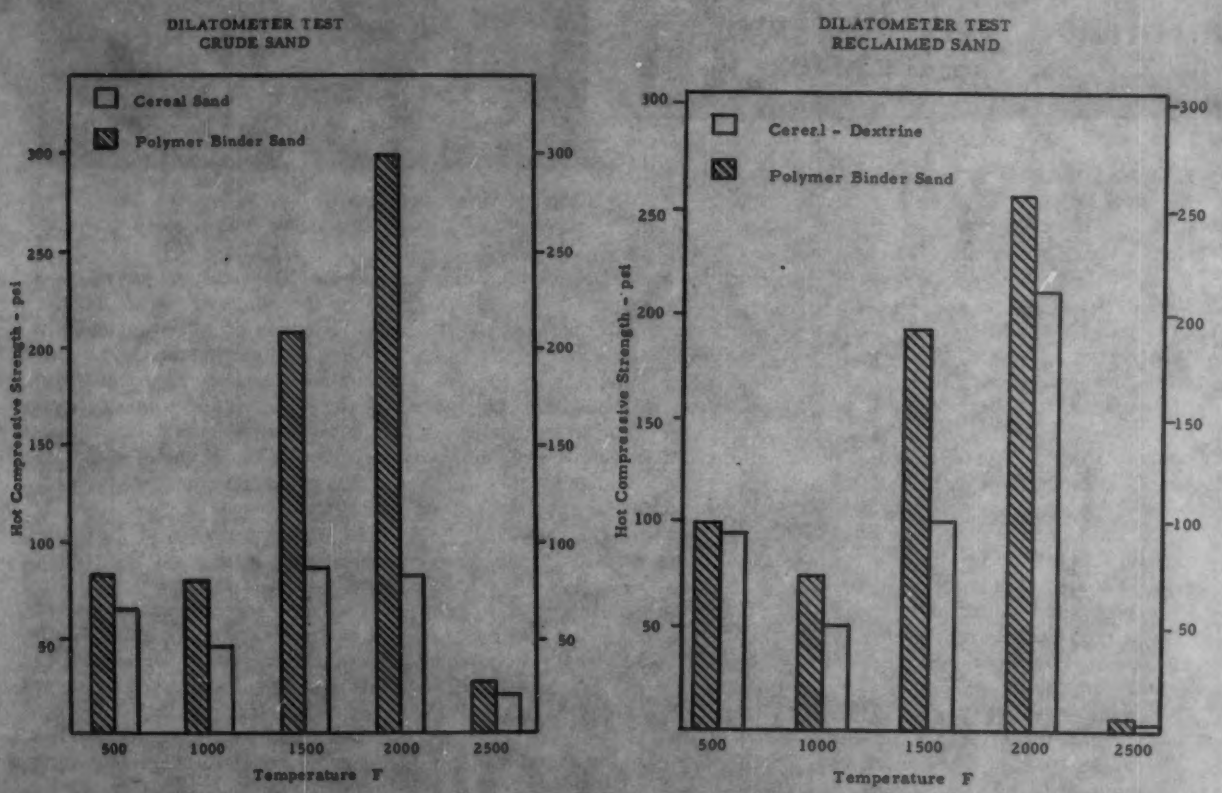
tized with carbonate should not be used. Sand fusion and burn-in may result in heavy sand peel and poor casting finish. Although this binder does increase the liquid limit of bentonite for improved bonding, it cannot increase the sand fusion temperature. This agent, when used as recommended, results in marked increase in hot strength in the critical 2000 F range where conventional sand has low strength. Dilatometer studies of typical new and reclaimed sand formulations have shown as much as a threefold increase in hot compressive strength over cereal bonded sand.

This binder can be used to advantage in most core formulations but at present this phase has not been fully investigated. Some work has been done in gray iron foundries with interesting results. The flowability was better, resulting in increased mold production. The shakeout, which had previously been a production bottleneck, greatly improved and sand recovery increased. Casting quality also improved with no casting rejects attributable to the molding sand. The small increase in sand cost from the use of the binder was more than offset by the increased production and a number of other benefits similar to those found in steel practices.

Summary

In summary, the new polymer binder displays the following advantages in foundry sands:

- 1) Requires only 2-5 per cent of the space needed for other binders.
- 2) Does not deteriorate over long periods of storage and has no food value for rodents.
- 3) Promotes easy, even mulling and transport of sand in foundry systems, with improved sand durability and stability without pH control.
- 4) Improves sand flowability; promotes higher rammed density with higher, more uniform mold green hardness.
- 5) Gives cleaner pattern release with better pattern draw.
- 6) Produces 90 per cent less gas in the pouring operation due to reduction in gas producing compounds.
- 7) Has better collapsibility and shakeout with increased sand recovery for reuse with less fines contamination and carbonaceous deposit on sand.
- 8) Gives good sand peel under proper conditions, resulting in cleaner and sharper detail to castings with over-all saving in foundry costs.
- 9) Yields over-all saving in foundry costs.



Two sets of column charts compare the hot compressive strengths of green sand mixes using crude and reclaimed sand with cereal and polymer binder.

Sand peels readily from these red hot castings as they come out of the shakeout.

Castings ready for shipment to customers display an unusually smooth surface with customer eye-appeal.

TABLE 1

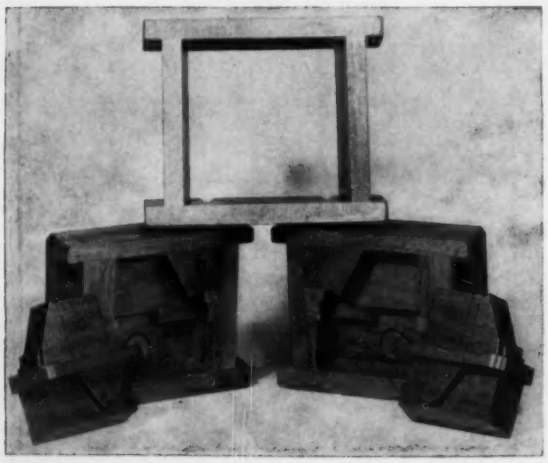
THE EFFECT OF POLYMER SAND BINDER ON MOLDING SAND PROPERTIES

Type of Sand and Additions in Pounds or Per cent	Per Cent Moisture	Flow	Green Hardness	Perm.	Green Comp. psi	Deformation in.	Green Shear	Dry Shear psi*	Air Dry Shear psi**	pH
ALL PURPOSE										
600 lb return sand, 5 lb western bentonite, 2.5 lb fire clay, 5 lb cereal	3.8 4.1	75 73	79 75	125 110	10.2 8.9	0.0375 0.0325	2.4 2.2	32 42	22 25	6.8 7.3
Same with 0.025% polymer binder and 0.025% $Na_4P_2O_7$ instead of cereal	3.6 4.0	80 80	82 80	140 125	10.4 10.2	0.035 0.030	2.5 2.4	30 39	20 23	7.2 7.5
RECLAIMED FACING SAND										
600 lb reclaimed sand, 23 lb western bentonite, 5 lb fire clay, 2 lb dextrine 5 lb cereal, 5 lb wood flour	4.0 4.1	75 77	76 78	100 100	8.9 8.6	0.0425 0.045	2.2 2.1	42 44	24 25	6.9 7.3
Same with 0.50% polymer binder and 0.05% $Na_4P_2O_7$ instead of cereal	4.0 4.1	85 84	82 83	120 120	9.1 8.9	0.035 0.0375	2.4 2.3	37 39	20 22	7.4 7.5
NEW SAND FACING										
600 lb AFS 510 new sand, 4% bentonite, 1% cereal	3.5	80	72	140	7.0	0.045	1.7	45	25	7.5
Same with 0.05% polymer binder and 0.05% $Na_4P_2O_7$ (no cereal)	3.5	85	80	150	7.5	0.035	1.9	40	24	8.1
BACKING OR HEAP SAND										
600 lb shakeout sand, 3 lb western bentonite.	3.9	75	76	105	7.5	0.035	1.8	30	18	6.7
Same after six weeks use of polymer binder in sands used above instead of cereal No bentonite	3.7	84	81	120	8.1	0.025	2.0	29	17	7.6

*Oven dried 110 C, 3 hr
**Air dried, room temperature, 24 hr

Patternmaker and foundryman should exchange ideas on all new pattern designs.

The patternmaker can often point out some cost-saving changes when an old pattern comes into the shop.



This well designed core box won first prize in the 1959 AFS Apprentice Contest.

PATTERN

by P. B. Groom
Houston Pattern Works
Houston, Texas

Pattern engineering and specifications need the respectful cooperation of all parties involved—the casting buyer, the patternmaker and the foundryman. The voluntary exchange of ideas between these three men is the first and most important step in this cooperation. This exchange of ideas could exist in a large plant manufacturing its own castings; it could exist in a plant having its own foundry and patternshop and making castings for outside customers; or it could exist between separate jobbing foundries and pattern shops making patterns and castings for a third party.

This cooperation is like a three-legged stool. Neither one nor two legs will keep the stool erect—it takes all three. Neither can any two of these three persons, customer, foundryman, or patternmaker, do their job effectively without the third party.

Forming the Team

Someone must want some castings made before pattern engineering can start. Next there must be a foundry to make them. But a pattern must exist before a casting can be made. We now have the customer, the foundryman and the patternmaker. Our team is now complete. While it is not always convenient to have all three together on the discussion, it helps greatly to arrive at decisions and to expedite the job. The alternative is to have a man experienced in the foundry or one experienced in patternmaking, and preferably having a fair knowledge of the other field. Such an individual can discuss the job with the customer. Then he takes the information received from the customer and works out the details with the third member of the team.

Many problems are involved that should be considered before a pattern is made. Some of the problems are: quantities of castings to be produced in a given time, probability of design changes, tolerances, machining problems, type of pattern equipment, method of molding, etc.

Types of Patterns

Patterns may be classified in a broad sense as experimental or one-time pattern, small quantity, long life, medium-high production and high production.

Pattern equipment must be further defined as either a loose pattern; match plate, single or multiple; cope and drag, single or multiple; dry sand or green

sand molds or cores; or special processes such as shell, D-process, or CO_2.

Pattern type is determined by the number of castings to be produced on an order or in a given period of time. Take, for example, a customer who places an initial order of fifty castings that can be made in a 12x18 in. flask. Total cost of a pattern and fifty castings would be less if he had the pattern mounted and gated on a board instead of making the castings from a loose pattern. Sometimes a customer will not recognize this fact so it is the obligation of the foundryman or patternmaker to point this out to the customer.

The question often arises, "Should the mounting and gating of a pattern be paid for by the customer?" Mounting usually results in a cheaper, a cleaner and more dimensionally accurate casting. If the saving passes on to the customer, then it should be considered a part of the pattern equipment just the same as a core print and core box. If a job is to be repeated and no design changes are contemplated, mounting and rigging a pattern is almost always advisable. This is the time for a buyer to seek the advice of the foundryman and the patternmaker unless he is extremely well experienced on this subject.

Molding Problems

From this point the foundryman and patternmaker can take over the more technical and detailed discussion and relieve the customer of many time-consuming conferences.

Many foundry problems merit consideration before a pattern is made. A large percentage of drawings are incomplete for reasons of economy in the drafting room. Many are not drawn to scale or are so complicated that a foundryman or patternmaker can't determine exactly how the job should be molded or how the pattern should be made. So a patternmaker's layout must be made for a detailed study. Often it helps to make a simplified model of the casting.

Before the pattern is made, the foundryman and patternmaker should agree on some fundamental and some special problems. The parting line, the cores necessary, core print clearances and sizes, loose pieces, shrinkages, whether the pattern is to be a mounted pattern or made loose—all must be considered. If made loose, provide for rapping and drawing the pattern from the mold. Decide whether core boxes should be single or multiple cavity, full or pasted.

Core Boxes

Let's consider the matter of loose pieces in core boxes. You may be making a production mahogany pattern and brass faced core boxes with brass faced mahogany loose pieces. But some of the loose pieces in valve body core boxes, for example, are thin sectioned. Such complicated wood pieces will not stand up under hard usage for over a few hundred castings. These pieces should be made of aluminum. Wood core boxes with aluminum loose pieces have been known to produce thousands of castings. And the loose pieces were still in perfect condition when the boxes had to be renewed.

Rapping plates and draw straps are essential on loose patterns. Draw straps with lifting holes at both ends provide means of handling heavy patterns by a crane at times other than when drawing them from the sand.

Core boxes should be made as a full box instead of pasting if the shape, size, and quantities make it advisable. Pasting a core is expensive and often leads to dimensional inaccuracies. If justified, boxes should be multiple and driers should be made when necessary.

Because a casting can be no more accurate than the pattern, all dimensions should be checked carefully.

What about machining problems? How many times have you seen castings scrapped because they would not clean up in the machine on the second or later operations? Castings with lugs, bosses, cored holes, flanges, etc. require more care in the first machining operation.

While it is not the job of a foundryman or a patternmaker to tool a job, it certainly comes under his jurisdiction to point out to the customer what the problem is and how it might be corrected.

Consider fillets in patterns. Many patterns are made without fillets. Sharp corners in castings cause cracks, stress concentrations, sand inclusions, etc. But patterns are sometimes bought without fillets because one patternmaker did not figure them in his price.

Some definitions of pattern construction quality are badly needed. You have no doubt heard a specification given as: "Four mahogany patterns on a board"; or "mahogany pattern, brass faced core box"; or (and this is my favorite) "Please quote price and delivery on pattern per print enclosed." What do all these so-called specifications mean? Absolutely nothing! Would you build a home or a plant building with only the floor plan for a contractor to base his price on?

Patterns in general do not involve enough money to justify engineering drawings as complicated as an architect's drawings of a building. But more important, how many people in the industry are capable of making that kind of drawing and specifications? No one person of my acquaintance has the knowledge and ability to put these details in writing. Yet patternmakers are asked to quote patterns with no specifications. Think what that means. He must mentally make a specification on his own and mentally convert it to dollars in competition with someone else who is doing the same thing. You can imagine what the results will be.

Wood Pattern Specifications

No specification can cover all types and sizes of wood patterns. Simply stating the number of patterns and the construction material does not mean much. Mahogany costs only about 20 per cent more than sugar pine. Remember, though, construction, not the kind of wood, makes the difference in pattern quality. A well constructed pine pattern will outlast half a dozen poorly built mahogany patterns. I've seen hundreds of patterns inspected by company inspectors and engineers without any consideration given to the actual construction because they did not know pattern construction.

A specification could be written to cover a narrow range of a certain type of pattern, such as valves. But a 30-in. valve pattern would not have any construction details in common with a 6-in. valve. The large one would probably be fabricated in sections and tied together with stringers, bolts or tie bars. The 6-in. body would more likely be made of solid stock, laminated or segmented, and fastened together by a trunnion. The thickness of lumber used, the direction of the grain of the lumber, the size and location of screws, the surface finish and tolerances of one would not apply to the other. Certainly the specifications on a valve pattern would not apply to a furnace door pattern or to a whipstock pattern.

Regarding core boxes the statement could be made that not less than two-inch material should be used. But the size, shape and production requirements will determine the thickness of the material. Even two-inch material is insufficient to keep extremely large boxes from spreading when a core is rammed.

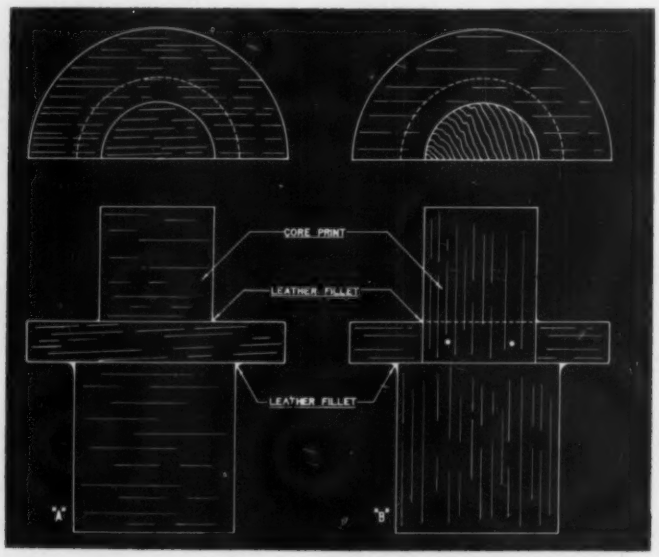
Metal Pattern Specifications

A sand cast metal pattern is satisfactory in some cases but it requires considerable hand work to make it usable. Such a pattern is satisfactory for ornamental work; but if dimensions and surface finish and sand inclusions mean anything, it is not. A pressure cast alumium pattern is a common type of match plate or cope and drag pattern for green sand molding. However, they have not proved satisfactory where close tolerances and fine surface finish are required. Extreme accuracy is best obtained by machining the aluminum patterns from rolled aluminum, or castings that have had machining stock added. Both pressure cast and sand castings have small gas holes that wear rapidly when used in a core blower.

When dimensionl tolerances of a few thousandths are required for shell, D-process or CO_2 method, patterns must be machined within very close limits. And this can't be done with conventional woodworking machines. A sand cast or pressure cast aluminum core box may be good on hand-rammed cores for some time. But if cores are blown in large quantities, machining the core box from rolled aluminum is preferable. Initial cost of the core box will be greater but the unit cost per casting will be less because of greater life and closer dimensions.

Whether-or-not Specifications

Effective pattern specifications must be specific and must be written for each job. Detail and assem-



Pattern "A" is an example of a poorly made wood pattern which has neither strength nor stability.

In pattern "B" the wood grain and method of attaching core print have been changed.

bly drawings as well as written specifications are needed if you expect a patternmaker to place an exact price on a pattern before it is made.

If someone came to you as a foundryman for a price on a casting, you would want to know the alloy, the heat treatment, the chemical analysis and the physical properties expected. Then you would need to know the quantities and the weight. In other words, you would want some specifications before you could price the casting. Castings can be inspected with magnaflux, x-ray and chemistry. Patterns can only be inspected dimensionally and visually.

Before a pattern is made, we should determine three facts: 1) what kind of pattern is to be made, 2) how it will be molded, and 3) (and most important) how it is to be constructed. Then foundryman, customer and patternmaker should cooperate to the fullest extent with each other.

No inexpensive and practical method exists for specifying the exact details of construction of a pattern. So a reasonable person could expect no more from a patternmaker in regard to a pattern price than that person is able to provide in regard to detailed construction specifications for the pattern.

Patterns are not manufactured commodities like bolts and nuts that are carried on the shelf and whose price is taken from a table in a catalog. Each pattern is a custom-made item which must be manufactured and priced as such.

I have stated that specifications to be effective should be specific. Here is just one example of the difference in construction of the same pattern that will perhaps illustrate this point. This example is a flanged end on a small valve or pipe fitting.

Example A

Sawed and sanded pieces are butted together with nothing except glue, a nail or a screw to hold them. The direction of the grain of the wood is based on time of fabrication and not on strength or stability. The grain running the way it does in this pattern is not good because it is weak and subject to contraction and expansion coming from atmospheric changes.

Example B

In Example B, the grain and the method of attaching the core print have been changed. This makes a better job but takes more time to construct.

Example C

The same general construction is used in Example C but with the addition of a tie bar. This method is better than "A" but poor because the tie bar is only on one face and does not offer stiffness to the pattern. The same principle applies here that would apply if you put steel reinforcing rods in only one edge of a concrete column. The grain running the way it does still does not give proper strength to the pattern.

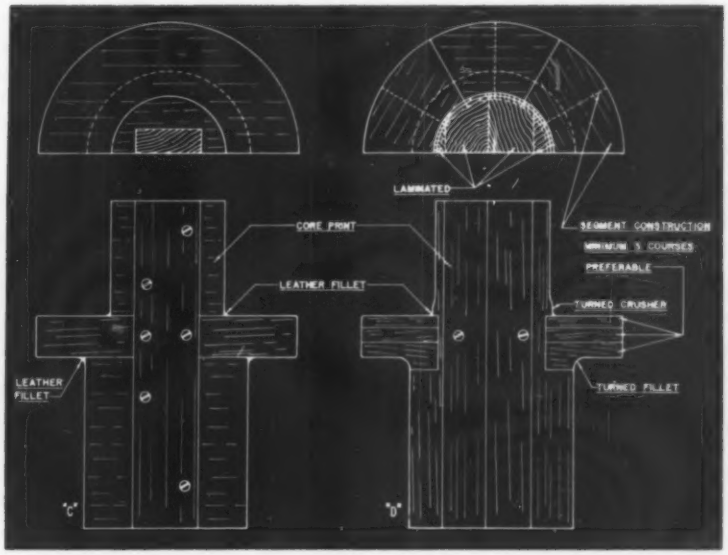
Example D

Example D shows an even better method of construction but one that takes considerably more time. Note the trunnion and core print are turned from wood with the grain extending through the entire length of the pattern. Usually this portion of the pattern can be turned integrally with the body or a trunnion extending through the body.

Though these examples are elementary to a patternmaker, it is difficult to understand why a mahogany pattern would be constructed by one of the first methods. Still they show up at the foundry, even with the core boxes brass faced. Perhaps someone ordered a mahogany pattern thinking he would get a production pattern because it was made of mahogany and brass faced. This is deceptive.

These remarks are made with respectful cooperation in mind. We can all gain something from further thought given to the subject. The foundry industry as a whole will gain by careful consideration and application of these principles.

Editor's Note: *How would you resolve this difficult problem that faces patternmaker and foundryman every time a new pattern is made? Your opinions combined with some AFS assistance might result in a solution to the enigma. Drop us a letter with your suggestions and we will keep the ball rolling.* ■ ■ ■



Pattern "C" has a tie bar added to one face only.

In pattern "D" the trunnion and core print are made with the grain extending through entire pattern length.

SAILOR-FOUNDRYMEN

by JAMES HURLBURT
U. S. Naval Station
San Diego, Calif.

How many foundries have you visited during your years as a foundryman? The number may vary but we think a visit to a shipboard foundry may be a new experience for you. So let's go to the U. S. Naval Station, San Diego, Calif., and inspect a foundry that cruises the seven seas.

As we walk down the pier that juts out into the harbor toward Coronado a huge bow with the designation "R6" is easily distinguished as it towers above the other smaller ships nearby. This is the U.S.S. Ajax . . . prominent in its magnificence and size . . . a fine repair ship of our fleet . . . a mobile navy yard . . . and a definite factor in keeping the operation of our world-traveling-seagoing forces at a constant high peak of efficiency.

Glad to Have You Aboard, Sir

After receiving permission to "come aboard" at the quarterdeck, our first stop is in the repair office. This office, located on the main deck just below the bridge area of the ship, is a beehive of activity. Many problems associated with the vital operation of the Repair Force are ironed out in this important center of activity.

Primarily, job orders are handled here, just as in your big plant front offices . . . with one exception. Meeting the deadline date in our case invariably means whether or not a ship under repair will get underway for some distant part of the world on a specified date. Some jobs may require a certain amount of up-to-the-last-minute sweating. But delays in sailing and loss of customers are practically nonexistent in our line. The foundry, along with the many other shops of the repair department on the U.S.S. Ajax, is an important factor in this important function.

Permission and clearance for a shop visit is given by the Repair Officer and PIO Officer. Then a short walk aft and two decks below the main deck brings us to the seagoing metalcasting shop.

Foundry Afloat

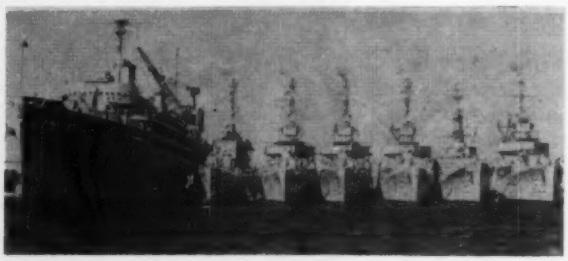
The foundry comprises three deck levels of the ship. Two of these are below the water line. Our metalcasting establishment compares with one of your three-story buildings of fair size on shore. However, it's quite likely that yours would not be walled and floored with solid steel. The top level is called the upper foundry; the middle level is called the lower foundry; and the bottom of the three is classified as the stowage space.

Most heavy work takes place in the lower foundry. This middle level handles molding, sand conditioning, melting-pouring, casting cleaning and finishing operations. Four indirect-arc electric furnaces set neatly around the molding floor. Off to one side is a Navy-type aluminum furnace (electric) that handles 700-800 lb of aluminum at one melting without any difficulty.

A stationary muller, portable gyratory riddles, and sandslinger conditions the natural bonded and synthetic sands. Smoke and gas exhaust from the shop through an efficient round-trip ventilating system. Three cranes service the lower foundry. A movable 6,720-lb capacity unit operates in the center bay. Port and starboard sides use cranes of 3360-lb capacity each. These shop cranes handle quite adequately any heavy shop work and lifting from the space below. Also on this middle-deck level of the foundry castings are cleaned and finished with a cabinet-type sandblast, sprue cutting bandsaw and two floor grinders.

An open, square-sectioned overhead space to the upper foundry permits good access to the topside of the ship. A boat-deck crane can lower down into the lower foundry level without any hindrance.

The bottom level of the foundry, stowage space, houses extra gear and supplies for the shop. Items necessary for upkeep, replacement purposes, molding needs, etc. are stowed neatly in this dry, below-the-water "backyard space." There's not much use looking for a fast delivery or scanning a colorful catalog when the ship is docked in Sasebo, Hong Kong, Okinawa or Subic Bay. So it's imperative for the shop-supervisor petty officer to stock up on refractory materials, sand and binders, crucibles, metal, spare parts and other vital items while the ship is in the "States."



The U.S.S. Ajax, on the left and marked "R6", is a Navy repair ship equipped with a sea-going foundry.

Nine men are currently assigned to the U.S.S. Ajax Foundry. These sailor-foundrymen wrestle with shop problems, travel to far-off lands, share each other's troubles, join in ship's drills, make liberties together and all in all team up as a well-knit group of molders in the service of their country. While serving aboard this large ship, the shop is their home-away-from-home. Commuting to and from work is no problem.

After completing their day's work the men may be found writing letters on the tables in the upper foundry, playing basketball in the do-it-yourself half-court in the lower foundry, playing cards, finishing a hobby project, studying, reading, working on an emergency job, or just plain relaxing on one of the cots that can be set out on the deck. Interest in outside foundry activities is evident in the fact that these seagoing-foundry-sailors are regular subscribers to MODERN CASTINGS and look forward to each issue.

Brass, bronze, aluminum, babbitt, steel, cast iron and monel are metals handled aboard a repair ship such as the U.S.S. Ajax. The size of castings poured, compared with your large shop jobs, may seem limited. But work completed aboard these seagoing foundries in most cases is adequate to meet needs for emergency ship repairs. Foundry service helps keep our foreign-operating ships at an efficient "at-sea" schedule while "running the bases" away from home. Some "for-instance" jobs that the Navy molders on the Ajax have completed are: a 450-lb bronze flapper valve, a 900-lb bronze billet, 600-lb cast iron lapping plate and a 6 ft, 6 in. high bearing requiring 800 lb of babbitt.

Molders of the fleet find it reasonably difficult to acquire firsthand familiarity with the most up-to-date developments that are being uncovered by the foundry industry throughout the country. Daily work and military obligations, traveling and other shipboard responsibilities seriously restrict their time for acquiring knowledge.

Fortunately, a rated molder of our Navy has the opportunity to overcome this handicap at the Advanced Naval Molding School—the only one in the Navy. Here is a definite go-between answer to the problem of keeping shipboard foundrymen in step with the latest developments in the field along with a sound review and extension of basic foundry knowledge.

The U. S. Naval Class B Molder School is located at the Naval Station, San Diego, Calif.—just a little south of the pier where the U.S.S. Ajax is tied up. Rated molders with sufficient time served in rate and sufficient time remaining to be served in the Navy are eligible to attend the 11-weeks of advanced instruction.

Rocking indirect electric arc furnace melting provides molten metal for Navy castings.

These sailor-foundrymen are putting into practice what they have just learned about the CO_2 process.

The two staff instructors at the school keep in close touch with industry by means of correspondence and actual contact. Instructors and students made a recent field trip to the Western Metal Exposition in Los Angeles to gain a firsthand viewpoint of the great strides being made in the metal industry. Visits are made to local foundries that employ some of the latest foundry methods so students personally observe the processes employed. One of the instructors attended a 2-day technical session on gating and risering sponsored by AFS in Los Angeles. Vacuum degassing, shell molding, CO_2 molding and coremaking, and the latest sand control methods are some of the areas where the instructors receive cooperative and helpful assistance from the field . . . and they do appreciate it.

As a supplement, current books on casting, metallurgy, foundry engineering and associated fields are a constant aid to the instructors in their relentless pursuit of the most modern and accepted foundry methods. Photomicrographs, films, charts and other training aids assist class presentation of the subjects.

The B School students use a large shop with ample equipment and facilities for the needs of the men. Topside, there is a sand test lab where tests for green compression strength, clay content and permeability are conducted. Moisture tests are made on the molding floor during heap sand preparation. Coreroom on the U.S.S. Ajax is in the upper foundry, but here at the school it is located at the rear of the shop, on ground level. Melting equipment includes furnaces, two indirect-arc electrics and a pit and tilt-type oil-fired furnace.

The four units covered during the 11-week period are: Unit One . . . Fundamentals of Foundry Practice;

Unit Two . . . Metallurgy of Castings; Unit Three . . . Casting Technology; and Unit Four . . . Foundry Management. One week of the 11 is devoted to leadership instruction—a vital phase of military life that is currently being stressed throughout the services.

Unit One . . . Fundamentals of Foundry Practice: This covers the three principal phases of casting production—molding, coremaking and mixing, and melting of metals. These subjects cover needs ranging from Third Class Molder to Chief Molder. Instruction includes physical and mechanical properties of cast metals and an intensive study of the intricate problems of sand selection and mixing (for molding and coremaking). Students are also evaluated in this first unit to detect any inherent weakness in subject understanding. Within curriculum limits the student's capabilities and all-round ability may then be appropriately strengthened.

Unit Two . . . Metallurgy of Castings: Study progresses from the atomic structure of metals and proceeds through the phase diagram and effects of elements on alloys. A basic understanding of metals and alloys is provided so molders may prepare and melt heats with an added insight into their chemical composition and the action that takes place in each case. Unit Two aids the student in molding and coremaking procedures to the extent that these procedures depend on the metals involved.

Unit Three . . . Casting Technology: This course probes into problems that actually arise in the Navy foundries. Each step and phase is approached from the standpoint of the metal involved. Parallel shop work matches the molding, coremaking, and melting-pouring processes with the subjects as presented in class. This intensive shop work provides the student with the ability to apply theory and instruction to actual shop practices and metalcasting needs.

Metals handled in this five-week unit are: aluminum and its alloys, pressure-resistant bronze, bearing bronze, yellow brass, manganese bronze, aluminum bronze, iron, steel, monel and stainless steel. Blueprint and pattern design, working procedures and heat treatments are other items covered in class. A clearer presentation of the carbon-silicon ratio for "as-cast malleable iron" was made possible in class by the use of a chart that appeared in the March issue of MODERN CASTINGS. Fluorescent penetrant inspection and x-ray of castings are introduced at this period of the course. The Naval Industrial Radiography School, Class C-1, is also a part of our service school's activity on the Naval Station. Here our casting x-ray service is handled.

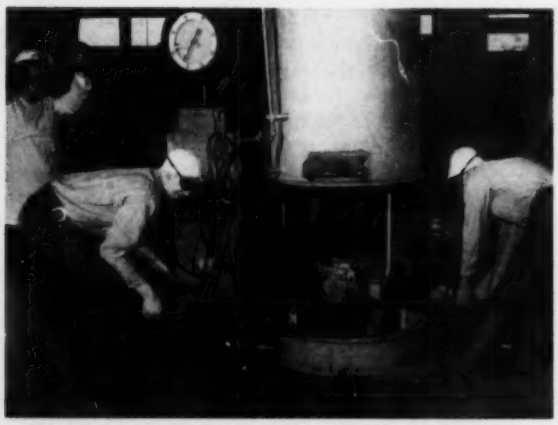
Unit Four . . . Foundry Management: Shop organization, personnel training and supervision, the importance of keeping good records in the shop, and employment of estimating procedures that are economical timesavers instead of hindrances are important phases of Unit Four. Most of the students are currently, or soon-to-be, shop supervisors. Therefore this emphasis on foundry management is a definite advantage, not only to the rated student but to the efficient operation of our Navy foundries.

Civil Service molders of the Station Repair Facility here also use the foundry along with the molding school group. Close cooperation between the School Staff and the Civil Service Crew, plus the mutual exchange of ideas and slants on foundry problems, becomes a definite reciprocal asset to both groups.

Graduation

The school was just established in 1956. Along with the "growing pains" in such a complex and ever-developing field, much is done to incorporate the latest developments of the field in the curriculum along with the good basic practices already set up in the course. The instructors aim to pass on to the shipboard molder this broadening combination of subjects which will ultimately result in continued competence, plus some extension of knowledge in the operation of our shipboard shops.

As the instructor and student (both petty officers) shake hands on graduation day, a feeling of mutual accomplishment and satisfaction exists between them. The successful instruction period, we feel sure, is a go-between answer to the problem of keeping our fleet molders in touch with the latest proven methods that can best benefit the Navy. ■ ■ ■



Everything's up-to-date in the Navy foundry and vacuum degassing of metal is the latest.

Since most of the work involves repairs it's not unusual to be casting propellers.

A Penny A Pound Knocks The H_2 Out Of Steel

■ The world's first production-type ladle vacuum degassing system takes only 12 min to remove 60 per cent of the hydrogen in a 75,000-lb heat of electric furnace steel. Cost of degassing is less than one cent a pound.

The system was developed by A. Finkl and Sons Co., Chicago, major producers of steel die blocks.

Principal advantage of this installation is that one degassing chamber can serve two or more furnaces.

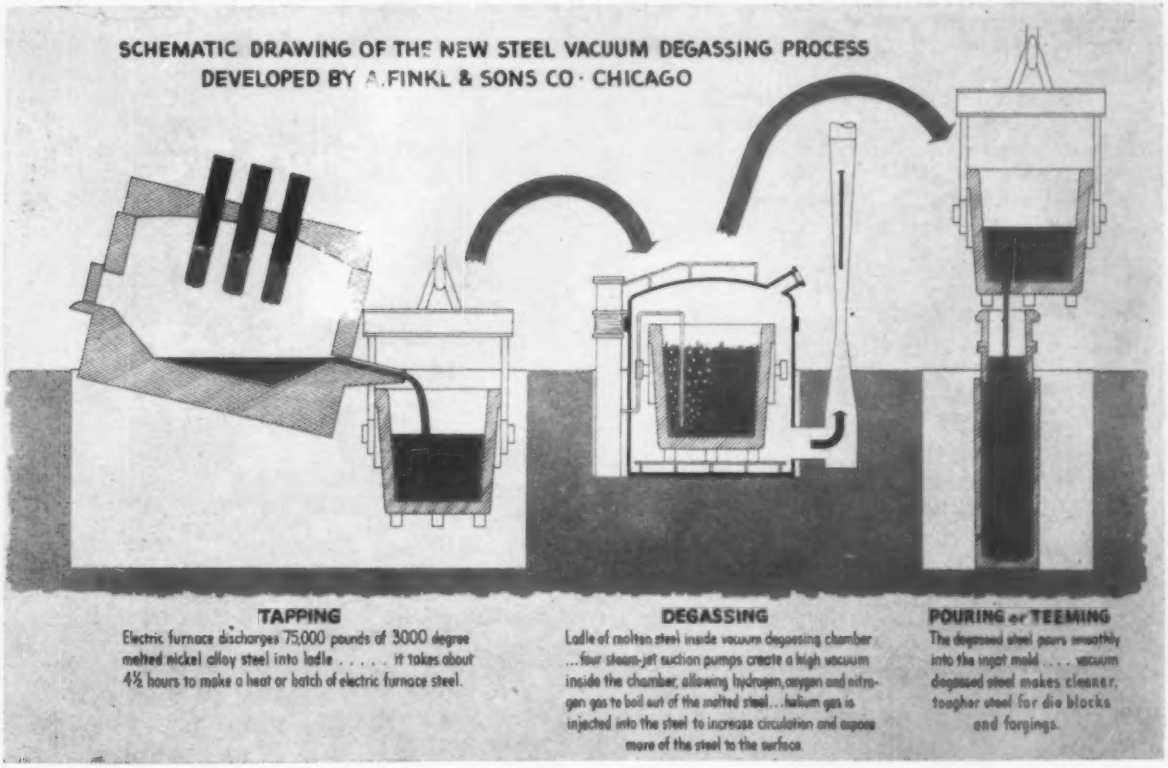
C. W. Finkl, vice president of engineering, stated: "The process should be of particular interest to foundries because the degassed steel can be poured into any number of molds by moving the treated metal from one mold to another."

The innovation in this system is the "snorkling" technique in which helium gas is injected into the steel while the ladle is in the degassing chamber. Bubbling helium circulates the molten steel and improves the efficiency of the boil-off of hydrogen, oxygen and nitrogen. Patents have been applied for.

The Finkl installation is currently reducing hydrogen content from an average of 3.9 parts per million down to 1.5.

A side effect of degassing is the ability to pour degassed steel at a temperature about 30 degrees lower than non-degassed metal.

Finkl Co. researchers consider their method applicable to steel foundry operations.


SCHEMATIC DRAWING OF THE NEW STEEL VACUUM DEGASSING PROCESS
DEVELOPED BY A.FINKL & SONS CO · CHICAGO
TAPPING
Electric furnace discharges 75,000 pounds of 3000 degree melted nickel alloy steel into ladle . . . . . it takes about 4½ hours to make a heat or batch of electric furnace steel.
DEGASSING
Ladle of molten steel inside vacuum degassing chamber ...four steam-jet suction pumps create a high vacuum inside the chamber, allowing hydrogen, oxygen and nitrogen gas to boil out of the melted steel...helium gas is injected into the steel to increase circulation and expose more of the steel to the surface.
POURING or TEEMING
The degassed steel pours smoothly into the ingot mold . . . . vacuum degassed steel makes cleaner, tougher steel for die blocks and forgings.

CASTING DESIGN... a modern art

by ALAN R. MOORE
Arnold Engineering Co.
Marengo, Ill.

In 1879 a two-mile-long railway bridge across the river Tay in Scotland blew down on a wild stormy night. A passenger train crossing the bridge at the time perished. The loss of life marked the date as a tragic one in Scottish history.

For the foundry industry this too was a tragic date. Apart from the shortcomings of the bridge designer, a post-mortem revealed that many of the castings used in the bridge construction were far from perfect. Besides porosity and cracks the castings contained gross shrink holes plugged with a home-made filler.

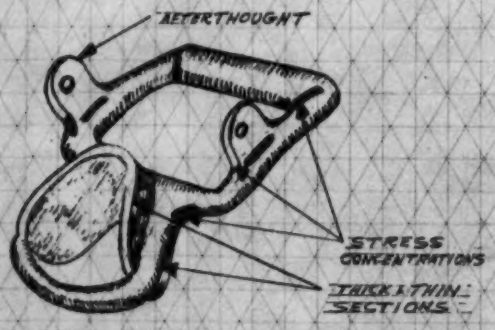
Ever since this tragic event designers have been looking beyond the foundry for more reliable ways of fabricating components. The famous Forth Bridge, for instance, a cantilever construction finished in 1890, was built entirely of tubular members, some measuring twelve feet in diameter. This bridge was built by a shipbuilder who used ship construction in his design, that is, riveted plates—and no castings. Even today, some firms, like Letourneau, shy away from castings as a matter of policy.

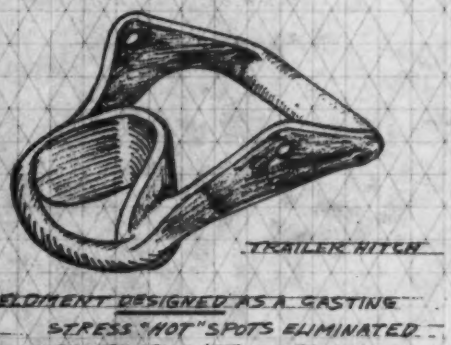
The questions now arise: is this suspicion of castings justified . . . is unreliability an integral part of a casting . . . . or does its method of manufacture make it unreliable? Where does unreliability originate . . . in the metal . . . in the manufacture . . . in the design?

Let's consider these questions one at a time and examine them closely, so that we may either mend our ways or close shop and go into the welding business.

Suspicion of castings is entirely justified. Founding involves no hocus-pocus or mysterious tricks. A casting is just what you make it. Luck is not a factor. In ancient times artisans would make all their molds in the floor, melt their metal, cut channels from the furnace to the molds, sacrifice a ram to Allah, after lengthy prayer tap the furnace and let'er go. Under such circumstances a miracle was imperative and the old boys knew it.

Nowadays, even in the midst of space technology, a great segment of the foundry world is not so very far removed from the sacrificial ram. How often have we tapped a furnace or tilted a ladle with a silent prayer or a fervent hope? Foundrymen are aware now as never before that control of the variables in the foundry is absolutely necessary to produce consistently good results. Yet in spite of this knowledge,



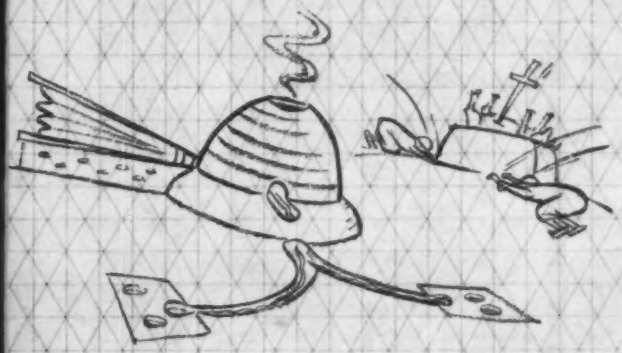


pouring a mold is still an act of faith. Somewhere along the line of the many hundred operations that go towards making a casting, from the idea to the finished product, there is some variable that seems to go hog-wild.

This brings us to the second question. Is unreliability natural to a casting or is it built into it? It can be positively asserted that unreliability is built into castings. The modern technology of stress analysis, aided by transistor and synthetic varnish, can show, as never before in history, how to find out exactly the manner in which a member is stressed in service. It can be shown that a perfectly designed casting, perfectly made, is stronger than a weldment, is lighter than a weldment, and usually cheaper than a weldment. It is even a moot point if cold rolled metal is superior to cast metal.

Surface finish and the immediate skin of a metal have a great bearing upon the ultimate tensile strength, a factor that is seldom taken into account in mathematical calculations of stress and strain. The casting skin is chilled and has a finer grain structure than the interior metal. This characteristic lends strength to the member. Indeed a designer of castings would do well to study the bone structure of an animal, particularly the cross section of a rib. He would see the hard but flexible skin and the spongy inner mass. The Creator is a good teacher. Since it is the skin of a casting that first bears the brunt of any load or stress, it is only reasonable to bring as much of it into play as possible.

All this adds up to the truism that a casting must be designed as a casting, not as a slavish copy of some prototype weldment. First and foremost a casting is a homogeneous piece. Don't make the gross mistake of regarding it as a conglomeration of I-beams and channel sections. Instead look on a casting as a metal sheet having a thickness consistent with the stress to be laid upon it, bent and twisted in the best way to carry the applied stress.



Stresses travel more or less in straight lines and although they can be gently guided they cannot be driven. Stresses do not take kindly to 90-degree bends and little or no fillet. When a casting is designed as a copy of some welded conglomerate, the casting is either overdesigned or will bring nothing but trouble to all concerned. Too many designers have a 19th-century table of shapes in their desk drawer along with a standard formula for each.

A mathematical knowledge of stress and strain is at best only a general knowledge—a mere guide. Failure in any member made by any method starts at a particular point. Therefore our knowledge must be particular—to be able to tell within one per cent what the stress is in any given 1/8-in. diameter circle. There is no welding company who would care to advertise the stress in service where the weld joins the parent metal, or at the root of a little fold of weld—even if they knew.

This is how particular our knowledge must be to get back metalcasting's lost market. It is one thing for a fabricator to assure a customer of the tensile strength of the plate he uses and the x-ray quality of his welds; it is entirely another thing to guarantee the strength of the weld. The strength of a chain is its weakest link.

Stemming from the same trouble source—design, comes another fountainhead of casting trouble. Every foundryman knows that casting shape is the difference between an easy job and a difficult one, or to put it another way, an expensive job and an economical one. A designer must bear in mind when using a casting that he has at his command an almost infinite variety of shapes. The foundry has what no other process has outside glass blowing—complete versatility in form. The neglect of this most valuable asset is not entirely the designer's fault. Part of the blame belongs on the pattern shop. The present-day pattern shop is as antiquated as our designer's table of shapes. After all, a sander and a planer have obvious limitations in regard to shape.

Much more advantage must be taken of modern materials, such as plasters, clay and fibreglas. Thus compound curves, tubular shapes and other inherently strong forms can be quickly and cheaply produced. In the matter of shape reproduction the foundry can claim one point ahead of both the pattern shop and the designer. With great strides made in metalcasting technology during the last decade, foundries can produce and indeed are waiting to produce the most complex shapes man can imagine.

Henry Ford is credited with saying: *"if it can be drawn it can be cast."* This was only half the truth. Actually foundries can produce castings of a shape that cannot be drawn.

Above all, however, a cast shape must be designed as a homogeneous unit. Remember that metal flows into the shape required, then solidifies. Therefore directional solidification is a must. Strive for uniform sections. Never forget that the runners and risers are just as much a part of the casting as the casting itself. Bosses and lugs that appear to have been stuck on as an afterthought are destined to be torn off.

It is astonishing how often one sees the mark of the backward designer—such as little ribs that add greatly to the difficulty of the casting job and seldom add to the strength.

The slick and trowel artist has been disappearing from the foundry scene. Production lines are commonplace. Patterns and methods are striving for simple, foolproof techniques. Chemical reactions are replacing the feather touch of a master molder. The profit-conscious, cursory glance is losing out to the x-ray film and the magnetic particle.

Foundrymen are busy proving that if it can be drawn by a designer, it can be cast.

But where can a young man learn how to gate and feed a casting, set the pouring temperature and go home confident? Is there a machine for this that a 36-in. cupola foundry can afford? Is there a formula that is more sure-fire than that with which those unhappy souls try to break the bank at Monte Carlo?

There is no such formula and never will be, so long as castings are designed with so little knowledge of the nature of materials and application of reason.

The plea is not for a return to artist molders—regrettably that day is gone, but for designers to get up to date—to learn what stress and strain are and how the foundry can help them reproduce economical, complex shapes. Just so long as casting shapes are the demand of the designer and not of the shape and magnitude of the load it carries, so long will pouring metal be done in faith. ■ ■ ■

1959 CASTINGS CONGRESS PAPERS

■ The technical articles appearing in this preview section of MODERN CASTINGS are the official 1959 AFS Castings Congress papers—the most authoritative technical information available to the metalcasting industry.

This issue completes the publication in MODERN CASTINGS of 93 technical papers presented at the 63d Castings Congress of the American Foundrymen's Society.

■ The complete case-bound volume of 1959 AFS TRANSACTIONS, including all papers and all discussion, will be published in January, 1960. Orders for this volume should be addressed to the Technical Department, American Foundrymen's Society, Golf and Wolf Roads, Des Plaines, Ill.

SHELL MOLDING DEVELOPMENTS IN THE AUTOMOTIVE INDUSTRY

By H. C. Grant

ABSTRACT

The details of the shell molding process at the author's company are pictured and described, covering details at the company's three iron foundries. The benefits which they receive from using the shell molding process in the foundries, in the machine shop and to the product engineer are given.

INTRODUCTION

To convert the foundry art into a science has been the long-range goal of learned professors, government agencies, private industry and the American Foundrymen's Society. The advent of shell molding onto the scene will not result in that long dreamed of "book" containing empirical formulas that are panaceas for all casting ills.

At the author's company it is no longer debated whether or not to further expand the shell molding facilities. Instead, the only question asked is which specific shell molding procedure should be adopted to any particular part (from the many adaptations now in production use).

The author's company has three iron foundries and one aluminum foundry in its Engine and Foundry Div. Two iron foundries have partially converted to shell molding, while the specialty foundry has shell molded exclusively since its origin in 1949. The aluminum foundry uses only die casting and permanent mold techniques.

To assure a uniform perspective, the author will first briefly review the shell mold process and broadly survey the general methods of application before specifically describing the different techniques used at the three plants.

SHELL MOLDING

The shell mold process consists of using resin as a binder instead of the conventional oil or cereal binders. The mixture of sand and thermosetting resin is placed on a preheated pattern. The residual heat melts the resin to form a gummy plastic which cements the sand grains together to a depth of $\frac{3}{16}$ to $\frac{1}{4}$ in. This hard crust formed against the pattern is a shell. When stripped from the pattern and assembled with another similar crust, a complete shell mold is formed. Some molds can be poured in this state. Others would rupture or distort from a more severe internal pressure created by the molten metal, and, therefore, require support from a relatively fluid backing material such as shot or sand confined by a flask.

INVESTMENT TECHNIQUES

There are three basic ways to apply this sand resin mixture to the pattern or core box:

1) The dump box method.
2) The strike-off method.
3) The blow method.

With the dump box method a sand resin mixture is dropped onto the heated pattern from an attached dump box. The dwell time (or investment period) is governed by the shell thickness desired, after which the pattern is rotated 180 degrees to drop the excess mix back into the dump box before it unclamps from the pattern. This method is used at the author's company for making our crankshafts, camshafts, gear cases and for the valve job deep-draw mold components.

The strike-off method is an excellent way to make a shallow-draw mold. Again, an excess of sand-resin mix is dropped onto a hot pattern. However, the sand comes from a stationary overhead hopper and the patterns are open faced and do not rotate about their axis. The excess mix is removed by a strike-off bar to produce a flat backed shell or mold section. Two of these sections, when subassembled with integral dowels, form what is called a "book." Several such books are piled up vertically to form a stack mold. Such molds require no backup and are merely clamped or weighted before pouring. Valve rocker arms are cast by this technique at the author's company.

With the blow method, a sand precoated with resin is blown into a pattern or core box cavity. Part or all of the metal surfaces in contact with the sand are preheated. Several variations of this method are used, but all have one common characteristic, i.e., the mold or core is finish formed and precisely dimensioned on all surfaces. Such molds obviously lend themselves to fixturized support. Thus, the company is able to permanently mold large intricate ferrous castings by using the shells as expendable, refractory liners. The company is approaching the semi-die casting of iron and steel.

In addition, there is a wide latitude in selecting from a variety of available sand mixes, namely; dry mixes, cold mixes and hot mixes.

H. C. GRANT is Mgr., Dearborn Iron and Special Foundries, Ford Motor Co., Dearborn, Mich.

Dry mixes are simple mixtures of sand with about 5¾ per cent of phenolic resin in dry, powder form. Such mixes are limited to use with the dump box method. They also tend to segregate and create a dust nuisance. The trend now is toward precoated sand.

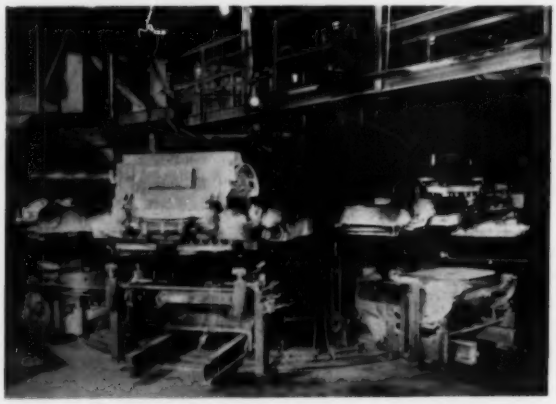
With cold mixes, the resin and a solvent (generally alcohol) are added to the sand at room temperature in a mixer. The alcohol dissolves the resin, causing it to flow freely and uniformly precoat the sand grains.

With hot mixes, the phenolic resin is brought into contact with heated sand in a mixer, where it melts and flow coats the sand grains. Subsequent exposure to the higher pattern temperature melts the resin and it cements the sand grains into a cohesive mass.

Further latitude is obtained by using resin for precoating in the powder, lump or liquid forms.

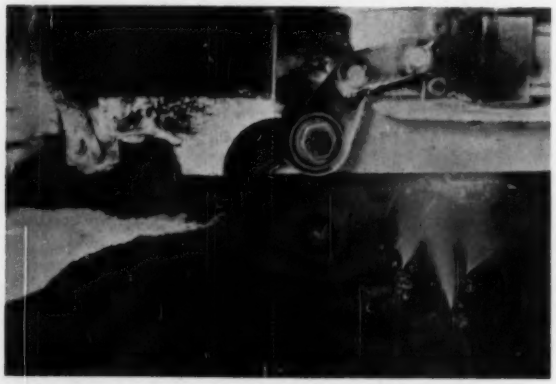
SPECIFIC SHELL MOLD DEVELOPMENTS

This section describes and illustrates the diversified techniques used to shell mold specific castings in the three iron foundries.

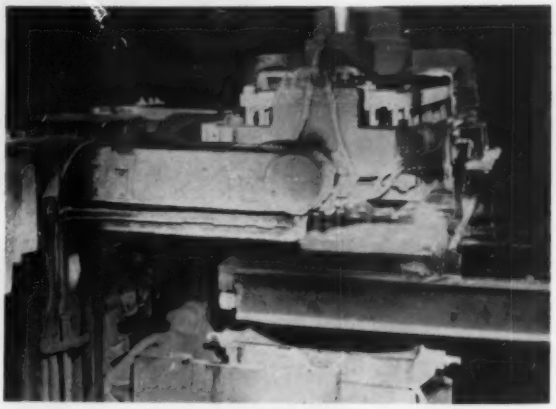


For the ductile iron crankshafts made in the specialty foundry the shells are made on this multi-station machine (shown in overall view), which has six spokes emanating from the hub. A pattern is mounted at the outer end of each spoke. The hub contains the "brain" to actuate the cams which control the series of operations.

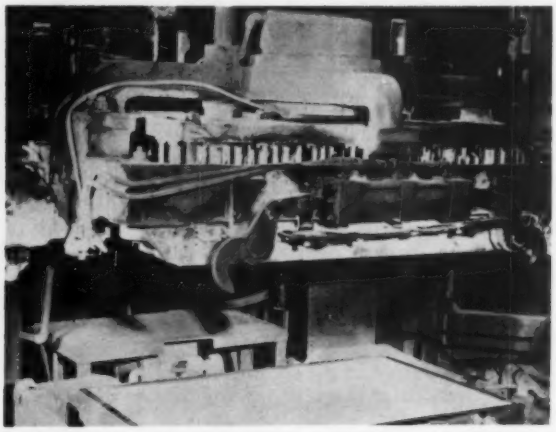
The patterns at the outer rim circle continuously; a complete cycle is made every 100 sec to produce six shells. Each of the patterns is simultaneously subjected to a different operation at the six stations. All operations are automated except the final shell transfer to the delivery conveyor.



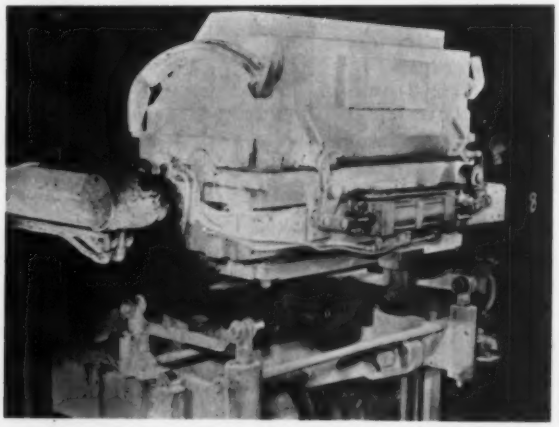
First, the patterns are sprayed with a liquid parting agent. This lubricates the pattern and lessens the shell's resistance to stripping. A 5¾ per cent water emulsion of silicone is used, constantly replenished and agitated to maintain a uniform concentration.



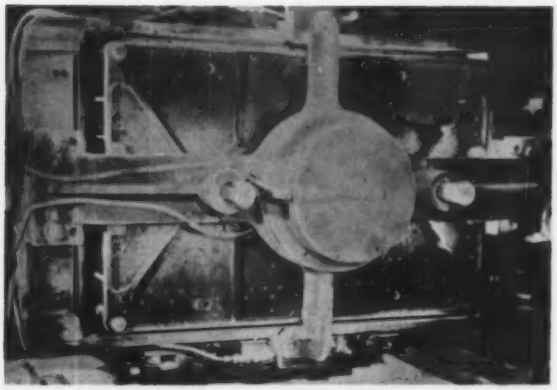
Second, the pattern is preheated over a multitude of low-pressure, open flame gas jets. The heat input is adjusted to exactly balance the combined heat loss at the other five stations.



At the third or investment station, the dump box clamps to the face down pattern, which then inverts on its trunion mounts. The pattern is shown in position for clamping.

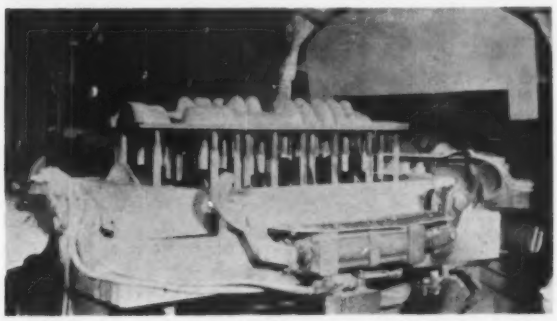


Gravity causes the sand-resin mix to dump on the pattern face. During the subsequent 8 to 10 sec dwell time (or investment period), the residual heat in the pattern melts the resin causing it to flow and smear the sand grains to a depth of 3/16-in. The gummy cement imparts sufficient adhesiveness to assure retention of the soft shell to the pattern during the subsequent rollover.



The rollover at station 4 returns the uncemented excess of sand-resin mix to the dump box. Also, the box is unclamped and the pattern inverted again for entry into the curing oven.

At the fifth station, the shell (while still in intimate contact with the pattern) is finish-cured into a hard crust within a gas-fired, refractory-lined radiant heater.

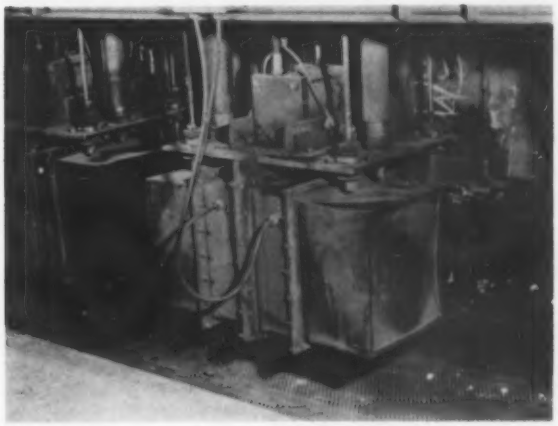


At the sixth and last station, the mechanical stripping mechanism integral within each pattern ejects the shell and positions it for manual grasp and transfer to the delivery conveyor. The ejected shell is shown on stripper pins.

Each shell contains 2 complementary rather than identical half-crankshaft cavities. Two duplicate shells are brought face-to-face for assembly into a complete mold. Thus, output and storage of copes and drags are perpetually balanced.

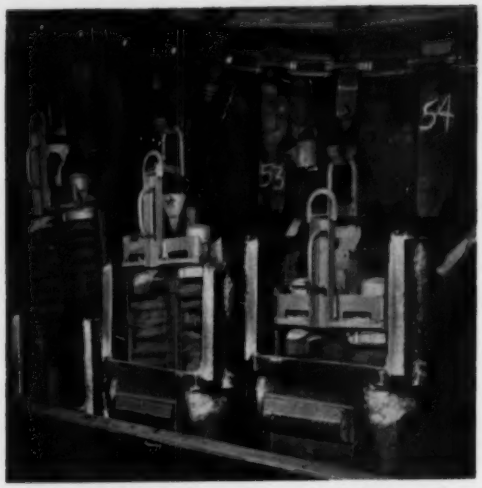
After two shells are fastened together with ten spring wire clips, the mold is manually inserted into a cylindrical, boiler plate flask attached to a pouring reel.

The open top, hinge bottom flask serves as a container for backing shot dropped from an overhead, gravity hopper. The shot fills all cavities within the flask to support the thin shell mold against the internal pressure of the liquid metal when poured.

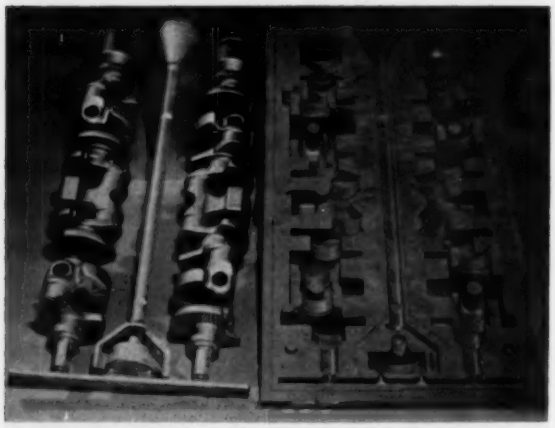


The flasks are automatically grasped by high frequency vibrators for 15 sec to thoroughly pack the backing shot.

The molds are poured with 1-ton bull ladles.

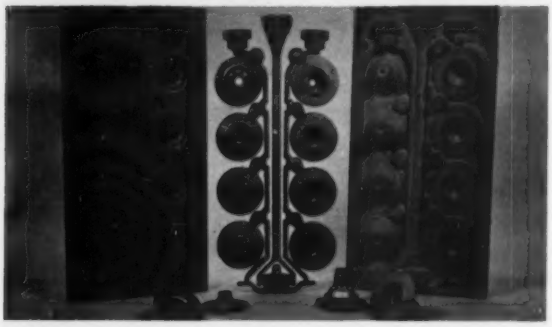


At the automated shakeout, the synchronized cooling line hangers grasp the clusters and convey them to the breakoff station. Thereafter, shot blasting and inspection suffice to ready most crankshafts for transfer to the machine shop.

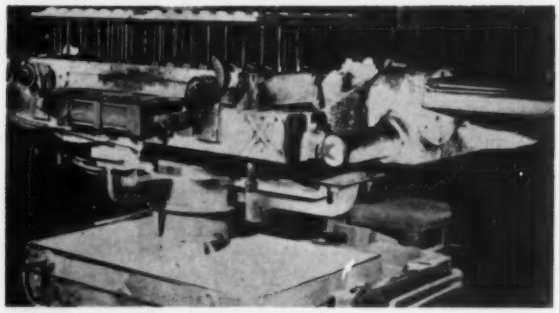


The preceding figure illustrates the shell details and the mating casting details reproduced. Note how the metal is channeled from the pouring cup into the sprue, then through a tangential gate to a slag trap wherein it acquires radial momentum to induce a swirling action that centrifuges out any slag or dross. The cleaned metal drops into the runner, then flows upward into the two casting cavities through the bottom gates with a quiet, non-turbulent flow. Note the interlocking locaters and the anti-dust baffles.

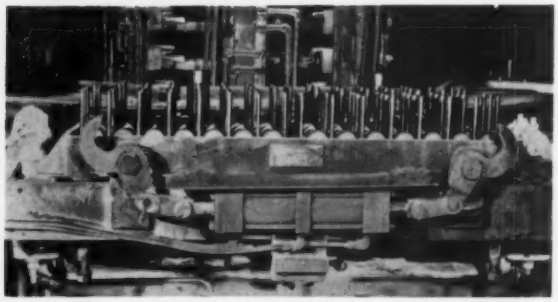
The preceding figure compares the internal and external shell details for a six cylinder crankshaft cluster. Note the integral mold sections used to core out the lightener holes.



The gear cases and cover used to house the rear axle differential gears are molded with a method almost duplicating crankshaft molding. The foregoing figure shows a composite view of gear case shell, shell assembly, cluster and castings.

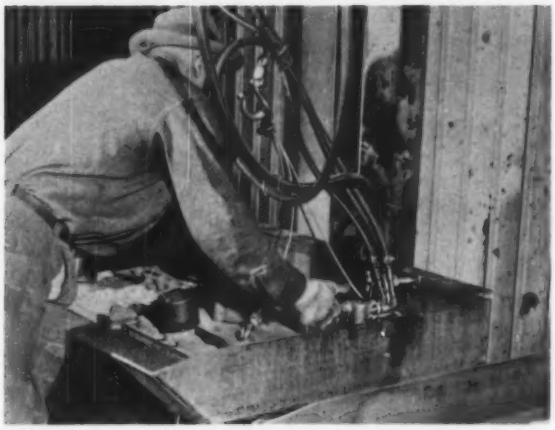


The camshaft mold making operation in the specialty foundry is identical to the crankshaft molding, except that 14-gang patterns are used, with the cope and drag patterns being separate and the molds are poured horizontally. The drag shell is shown on the stripper pins. A second machine simultaneously produces cope shells.

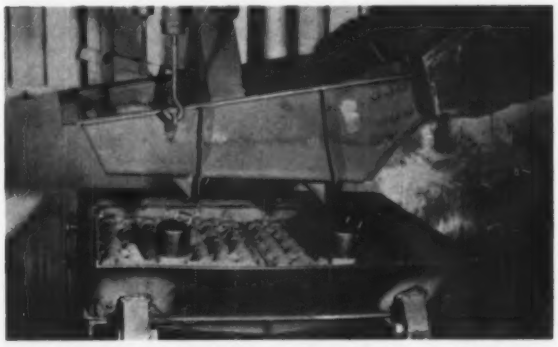


The shell has been removed in the preceding photograph to permit a study of the compact pattern layout which maximizes the castings per mold, and minimizes the material cost per casting.

Two camshaft mold assemblies are laid on a metered cushion of bedding shot positioned in the flask. The open top flasks hang from a pouring reel.



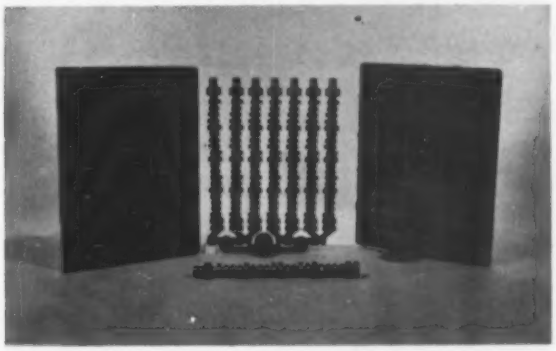
The molds are then vibrated to shape the bedding shot to the mold contours and assure overall support.



Shot is then automatically metered from a gravity hopper to weight the mold against the internal pressure of the molten metal.

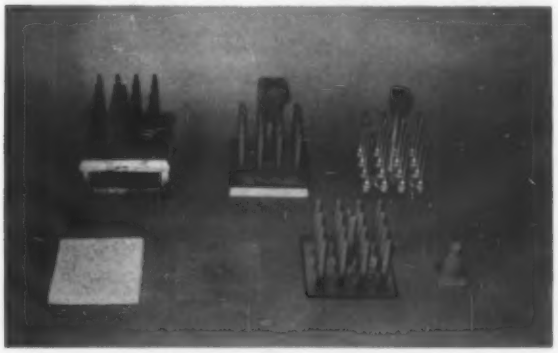
The molds are poured with a shank ladle.

At shakeout, an automatic device pneumatically tilts the flask to eject the clusters onto a grating. The shot drops through the grating for recycling.



This composite view emphasizes the compact shell layout which utilizes every sq in. of pattern surface to form casting and gating cavities, interlocking locaters or stripper pin contact.

Note particularly the excellent definition and the absence of parting line flash.

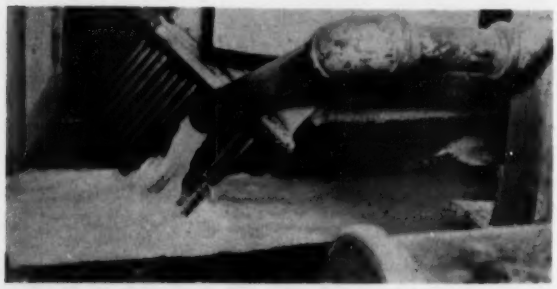


The exhaust valves were the first part shell molded in the author's company. In the figure you see on the assembly in the background, the four mold components. The light colored runner core in the lower left corner is made by blowing; the ⅛-in. thick gate core is made by the strike-off method; the valve core and runner cup cores are made by the dump box method. In the upper left corner is a valve core pattern; at top center is a complete mold assembly and on the far right the 16-gang casting cluster which it produced.

The runner core is blown in a two-gang core box with plain uncoated sharp sand mixed with a powder resin binder. It is cured in a dielectric oven.

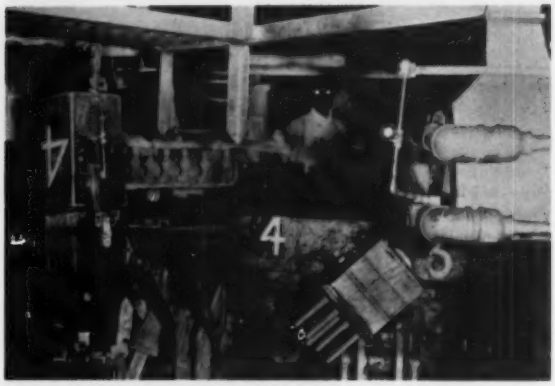
The gate core is made by the strike-off method, which has been found an economical way to make shallow-draw, flat-backed mold sections. The gate core shown, incidentally, is only ⅛-in. thick.

This view shows the gate core after finish-cure in the oven, ready for manual transfer to the delivery conveyor. This is the only manual operation on the 12-station machine.



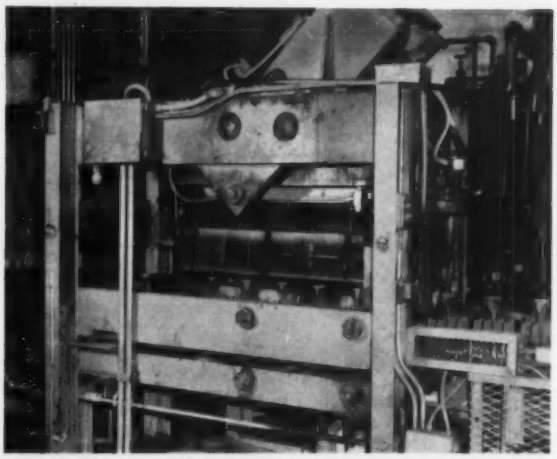
This figure shows a valve pattern cycling through a dip tank containing a 1.5 per cent silicone emulsion. An excellent pattern lubricant is necessary to facilitate draw, since the pattern stems have only 0.003 in. total draft in a 5½ in. length.

For this mold component, a precoated sand is used, prepared by hot coating with a novolac lump resin. A stearate ingredient added to the mix imparts a self lubricating property to the shell which enables the silicone concentration to be reduced from 5 per cent to 1.5 per cent.

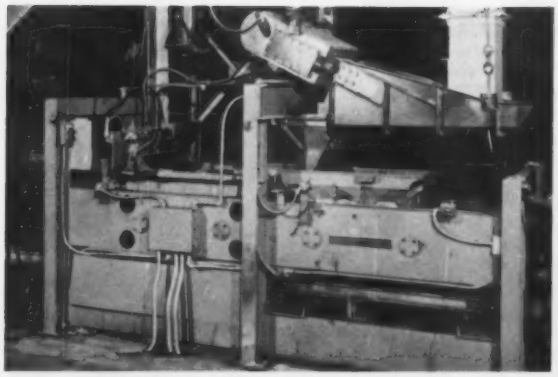


The valve pattern at the left (or no. 4) is being invested on this 15-station shell making machine. At right, the dump box (no. 3) has just unclamped from the pattern after completing investment. The invested pattern is rotating into position for finish cure of the shell in the radiant heat oven at the far right.

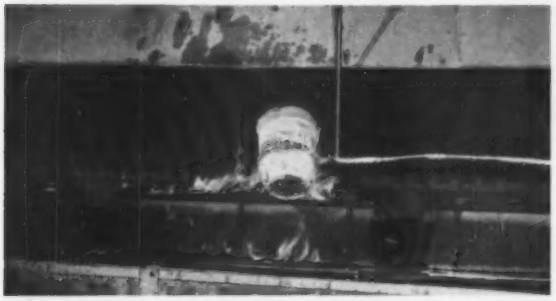
The valve shell, on emerging from the oven, has been lifted from the pattern by the integral stripper pin mechanism and is positioned for manual transfer to the delivery conveyor. This is the only manual operation on this 15-station machine.



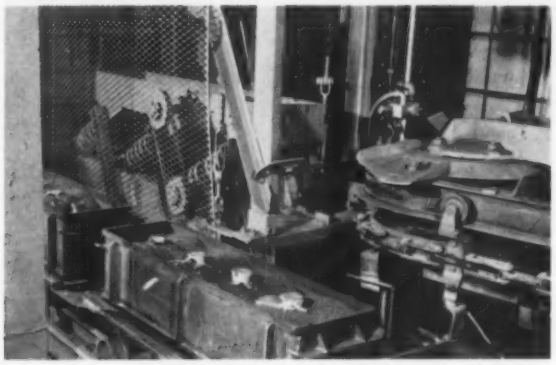
A flask is being automatically positioned around five complete mold assemblies that will produce 80 valves. The forward travel of the flask positioning device is synchronized with the constant mold conveyor travel.



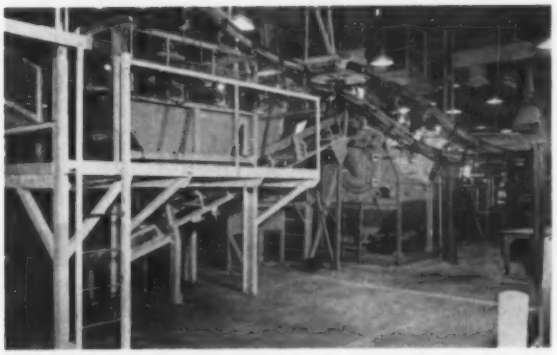
The four mold components in each assembly are self-located with interlocking locators; no fasteners are used. Shot is automatically metered from a gravity hopper to prevent separation of the mold components by the internal pressure of the molten metal.



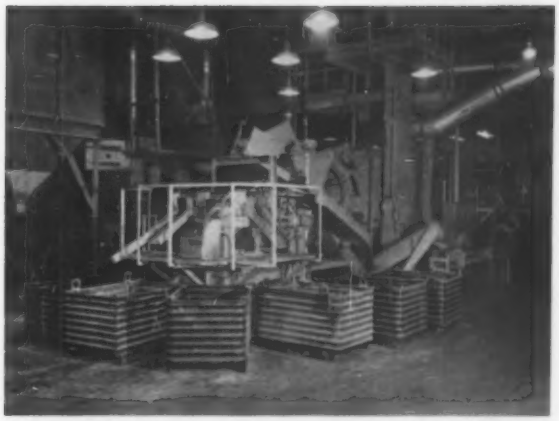
Metal is poured into the valve molds at a temperature of 2940 to 2960 F.



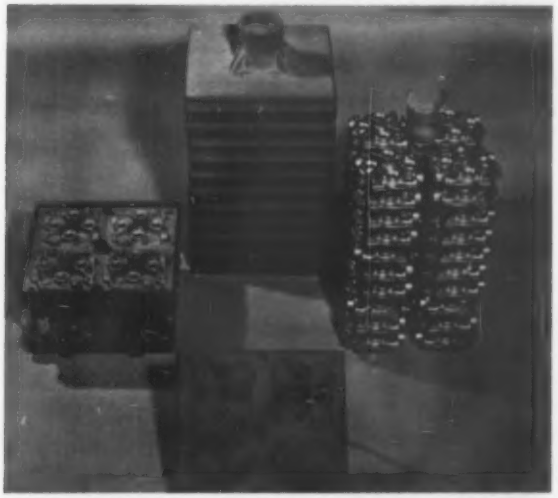
Shakeout of the valve clusters is automatic.



After cooling, the clusters then enter an automatic break-off service which breaks the castings from the gates.



The valves then enter an automatic sorting and inspection machine which routes the various types into a shipping container.

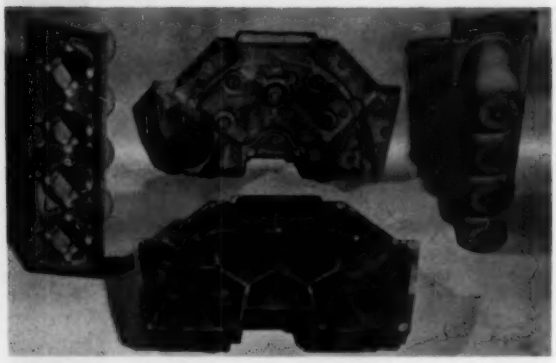


This figure will permit a perspective study of why the strike-off method was chosen to make the rocker arm castings. The shallow-draw, flat-backed mold section in the foreground is made in the pattern at the left. Two such sections are paired to form a sub-assembly called a "book." Ten such books are piled vertically and topped with a pouring cup core to form a stack mold. The complete mold produces the 160 casting cluster seen at the right.

All rocker arm mold sections are made on this 22-station machine. The only manual operation is the transfer of the shell to the delivery conveyor.

The rocker arm molds are poured with a bull ladle synchronized to keep pace with the mold conveyor. Note how the entire shell mold has become red hot before pouring is completed. However, no cracks or mold distortion develop from the thermal shock or the ferrostatic pressure exerted.

The cluster continues on, and after cooling is dumped automatically off the pouring line into a tumbler which performs the dual function of separating the castings from the gates and also cleaning them. They exit from the tumbler onto an inspection and separation belt and then drop into the shipping containers.

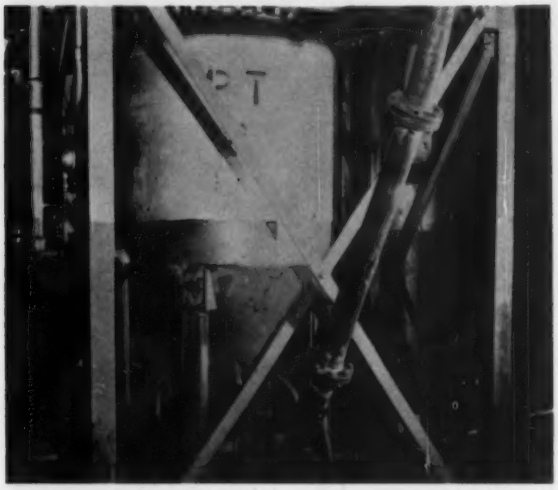


One iron foundry (the largest foundry) is converted to blowing the following hollow shell cores for the cylinder block and the rear axle carrier case:

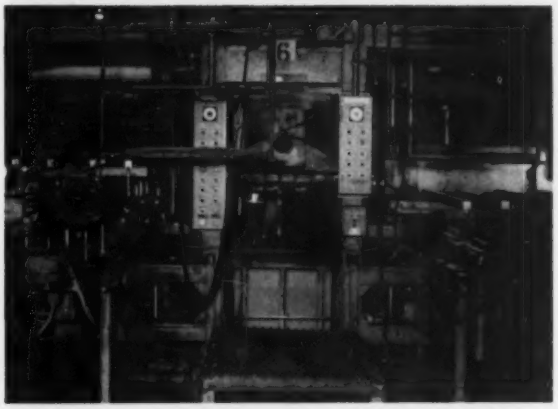
Barrel cores.
Flywheel end cores.
Gear end cores.
Valve chamber cores.

In the foreground of the figure is the hollow shell core used for the rear axle carrier case. Other conversion than shown is in the development stage.

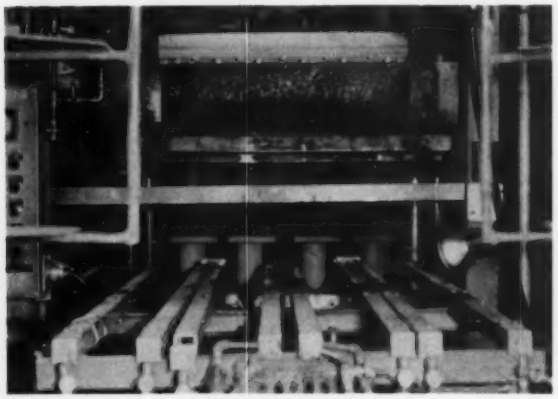
Sharp sand is used exclusively in this foundry. It is precoated by the warm mix method at 200 to 250 F using a liquid resin with an alcohol vehicle.



The precoated sand is pneumatically conveyed in tubes to the hoppers above the top-blow shell making machine.

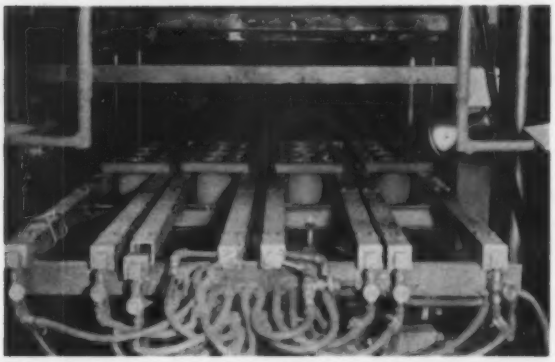


This frontal view shows a two-station blow machine used to make cylinder block shell cores. While an operator on the center platform transfers to the delivery conveyor the four cores ejected from the left-hand station, four additional cores will be blown, cured, stripped, trimmed and ejected at the right-hand station. The cycle is automatic.



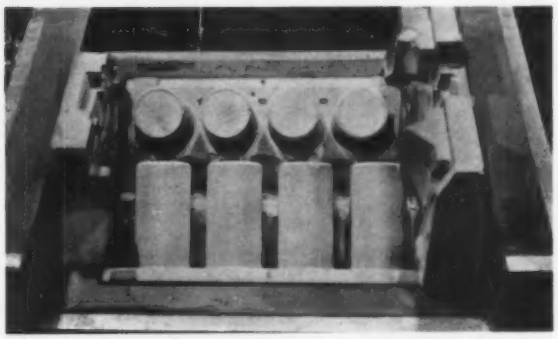
Here you see four barrel cores after blowing, curing and

stripping from the four-gang core box. Note the strike-off bar to automatically knock off the blow tips.



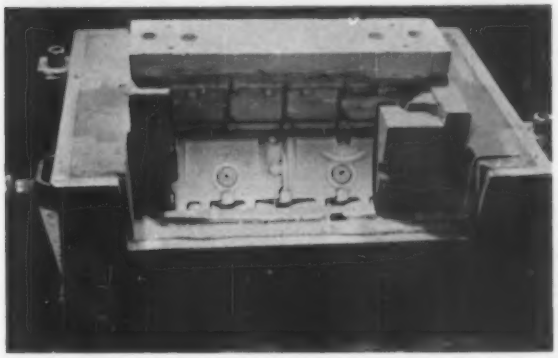
The same barrel cores are shown in this figure after the blow tips have been struck off during automatic transfer onto the ejection ways.

These two repeat views of the previous two figures show the gear end cores being made. They illustrate the versatility of the machine for any core with a change of patterns and a simple adjustment of the ways.

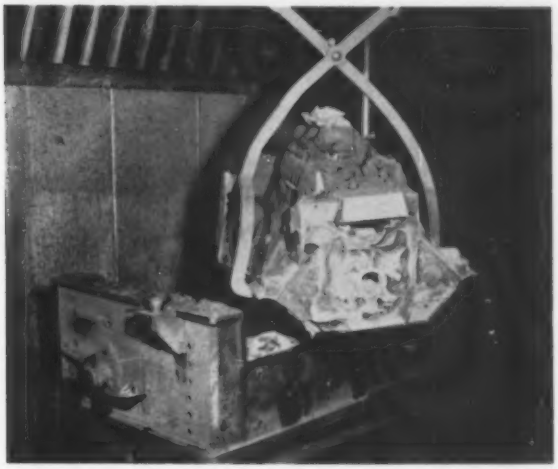


In this figure are a valve chamber core, two barrel cores, the flywheel end core and the gear end core assembled into a green sand drag. Any extended delay in finish assembly or pouring off would not result in any moisture pickup by the cores from the moist green sand.

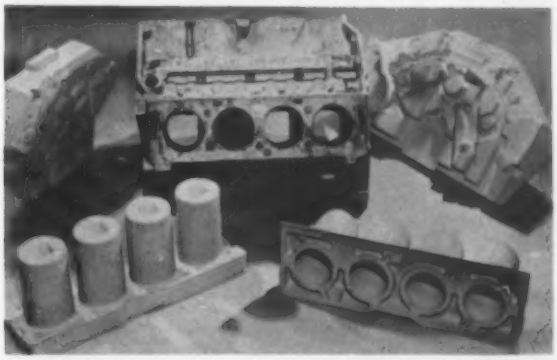
The shell cores require no wires, arbors or extensive venting; They are hollowed to reduce weight, conserve material, evolve less gas and to facilitate collapse during contraction of the casting. They are ribbed for rigidity and strength. Also, they resist erosion during handling, can be precisely assembled and give good definition. The conversion from oil-cereal cores reduced the barrel core weight from 22 lb to 13 lb, and the flywheel end core from 31 lb to 14 lb.



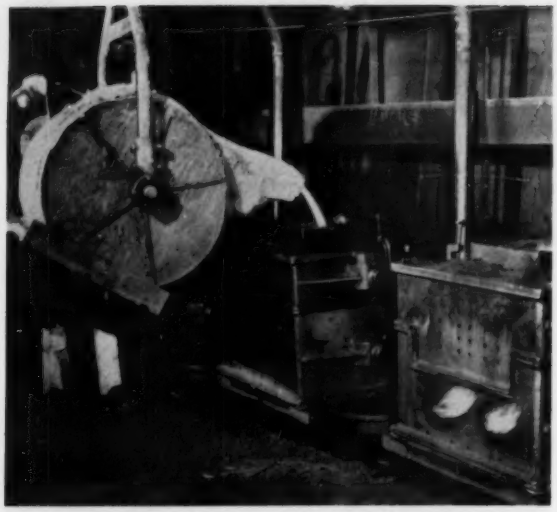
The remaining baked sand cores not yet adapted to the shell technique have been assembled and the cope will be lowered to complete the mold.



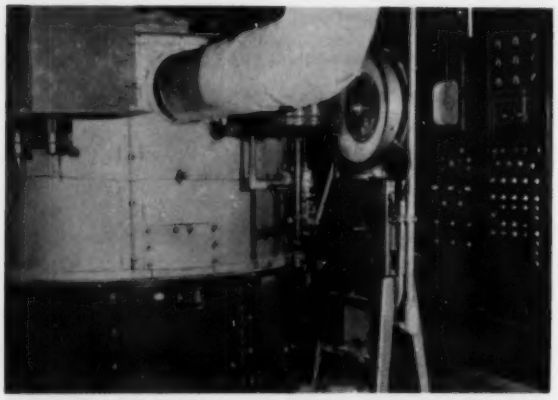
Note on this block at shakeout how the shell cores have disintegrated, and the sand has run out freely from the cored cavities. A core knockout operation is no longer required in the shell core areas.



At the other iron foundry, a substantially similar technique is used to make the cylinder block cores with equally gratifying results.

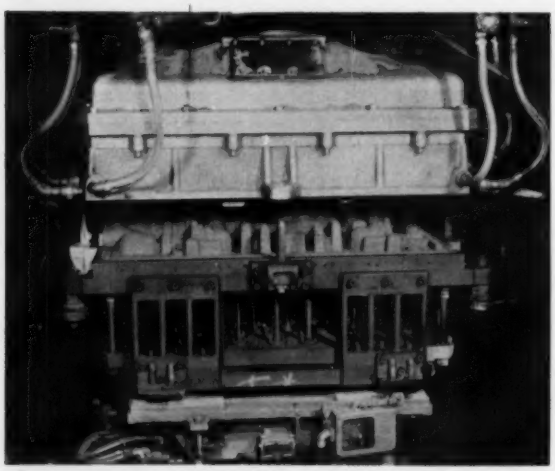


Note the reduced gas evolution resulting from even a partial use of shell cores.

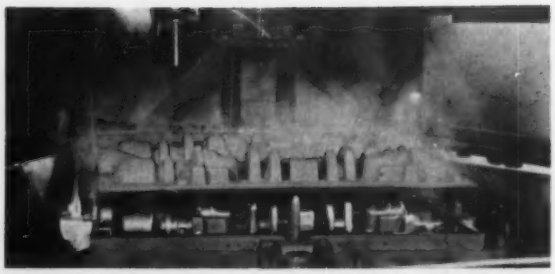


All sand used at this foundry is precoated. The centralized control panel permits instant and precise adjustment of the pre-coating process in the mixer at the left.

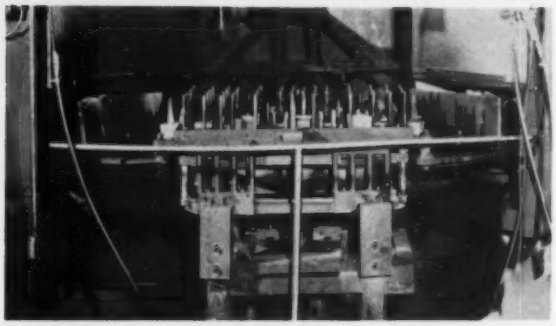
The crankshaft molding technique at this foundry is perhaps the company's most advanced shell mold development, and is at present undergoing even further development. The shells serve as expendable, refractory liners inserted into permanent molds.



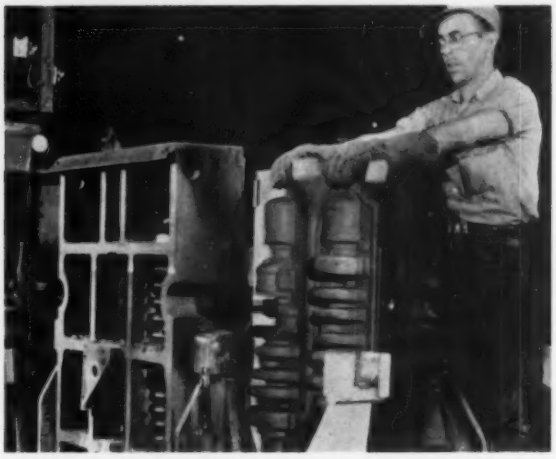
This view of the six-station shell blowing machine shows the blown and partially cured shell on the pattern.



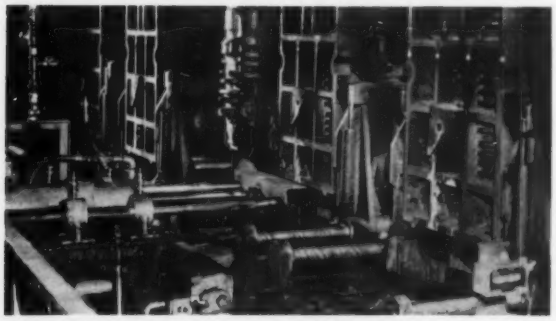
Here the cured shell has been automatically stripped from the pattern by the integral stripper mechanism and will be manually transferred to the delivery conveyor by the lone operator.



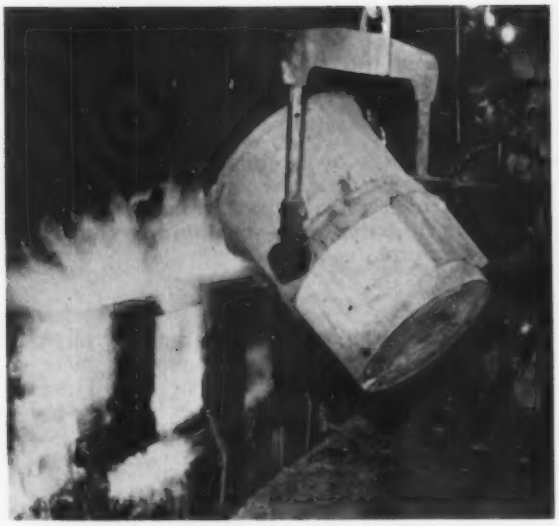
The same station with the shell removed gives a clear view of the stripper pins which are actuated by a cam-controlled stripper plate.



The shell assembly without any fastening is manually inserted into the permanent mold to act as a refractory liner.



This closeup view shows the hydraulic apparatus which automatically closes the dowel-aligned molds.

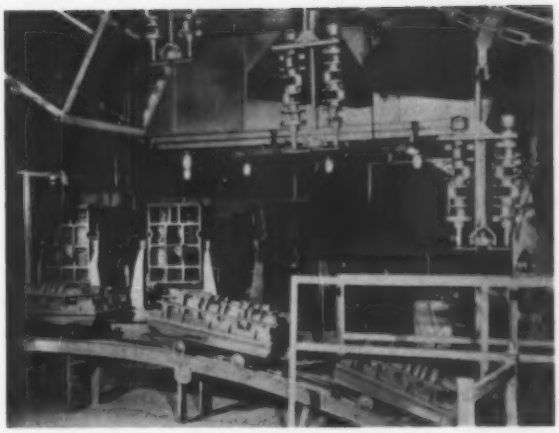


A bull ladle is used to pour the mold.

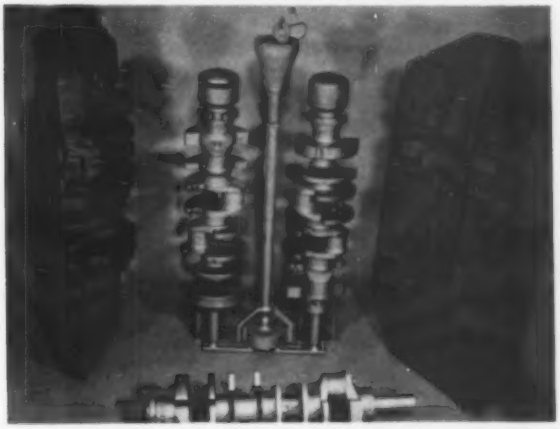
A hydraulic mechanism automatically opens the permanent molds at shakeout.

This close-up view shows the opened mold with the crankshaft cluster ready for automatic knockout by a ram. This action also transfers it to the synchronized cooling line which is descending into alignment.

No vibration is required at shakeout thereby reducing the noise level. Also, there is little fuming. Fatigue has been eliminated from what has traditionally been the foundry's most fatiguing operation. The reduction in noise, smoke and dust at shakeout makes the entire foundry healthier and cleaner.



This figure shows three related conveyors — the shell conveyor in the foreground which delivers the liner assemblies to the pouring line, the pouring line itself in the background and the cooling line overhead which transfers the casting clusters to the cleaning room. Note particularly the as-cast surface finish of the castings and the absence of parting line flash. The castings will require no warp check, being uniformly straight. They remain on the hanger for shot blasting, visual inspection and loading into shipping containers.



This composite picture permits a detail study of internal and external shell design, the as-cast cluster and the flogged crank before cleaning. The gate and riser design generally adhere to the principles discussed previously.

BENEFITS FROM SHELL MOLDING

Specific Experience from Conversion of One Part to Shell Molding

The company's specific experience with the crankshaft can best illustrate the benefits gained by the foundry, the machine shop and the product engineer from the conversion to shell molding.

In the Foundry

1) A wider range of pouring temperatures can be tolerated.
2) Stress-relief heat treatment is eliminated.
3) Only 30 per cent of the metal poured need be remelted—a gratifying yield. Also, all the back scrap is so sand-free it needs no cleaning to prevent contamination of the melt.
4) Shell molding permits the use of the latest and most advanced principles of gating and risering. These molding features can be incorporated in-

tegrally in the shells on a cost-free basis, rather than by use of extra mold components.
5) Foundry scrap has historically averaged only a fraction over 1 per cent and foundry machined scrap less than 0.5 per cent.
6) The operations are less fatiguing, less noisy, less smokey, cleaner, safer and healthier. To climax this statement, it can be cited, with excusable pride, the company's world record set recently for accident-free operation by an iron foundry.
7) Much less floor space and equipment is required.
8) The operations are readily automated.

In the Machine Shop

1) Finish stock removed during machining and balancing has been reduced from 9.5 lb on the dry sand molded crankshaft to 5.5 lb on the shell molded casting.
2) The precise counterweight spacing enables elimination of entire batteries of cheeking lathes.
3) Cheek spacing is controlled within $\frac{1}{32}$-in. Also, the counter-weight O.D.'s are cast with such close tolerances that running clearance in the engine is assured without prior machining. To cite a striking example, in one recent model year over a million crankshafts with calculated clearance of 0.0285 in. between one cheek O.D. and the camshaft distributor gear were assembled into engines without a single incident of interference.
4) Tool advance in rapid traverse is maximized because of less finish stock and precisely positioned diameters. Also, the counterweights do not interfere with the lathe tools and grinding wheels.
5) Chip disposal has been reduced 42 per cent.
6) Tool life is extended by the absence of chilled spots, chilled fins and sandy surfaces.

To the Product Engineer:

Functionally, or from the product engineering standpoint, the benefits have been that the designer can provide close running clearance in the engine without injecting extra machining expense and can minimize the weight.

SUMMARY

In summary, shell molding has not only increased the mold material cost but also requires more expensive patterns and molding machines. However, the increased productivity per man, and the reduction in secondary operations, has more than offset these increased costs, especially in view of steadily rising labor rates.

Better and safer working conditions attract and conserve a higher grade of personnel. A more compact layout and less critical process controls further reduce total cost.

Less tangible perhaps, but undeniably potent, are the long-range benefits accruing from consumer satisfaction and design flexibility.

The competition inherent in the free enterprise system will continue to stimulate a series of technological breakthroughs that must inevitably culminate in reaching this goal.

INDIRECT ARC ELECTRIC FURNACE PRODUCTION OF DUCTILE IRON

By L. Miller

ABSTRACT

The general aspects of a method of utilizing the indirect arc rocking type electric furnace for producing high quality ductile iron castings is given. A description of the furnace, its use in ductile iron production, chemistry control and the plunger ladle is presented. A detailed tabulation of the furnace heats over a period of time, the composition and properties of the metal, are brought forth by the author.

INTRODUCTION

The types of melting furnaces that can be adapted to produce ductile iron base metal are, in a broad sense, limited only in their ability to impart sufficient temperature to the melt. However, composition and temperature of the base metal prior to the addition of magnesium are of fundamental importance in the process of producing ductile iron. Therefore, some types of furnaces under certain conditions of operations are more suited to ductile iron production than others.

The probability of two or more foundries operating under identical conditions in every respect is remote, and only by careful study and understanding of the factors that determine the overall manufacturing costs can the individual foundry arrive at a simple, economical method which best suits its particular requirements.

In addition to the ingenuity of management, factors which influence or determine the overall manufacturing cost of ductile iron are the manufacturing facilities, the quality and type of castings produced, the production requirements and, of course, the method of introducing magnesium into the base metal.

In general, a method of utilizing the indirect arc rocking type electric furnace for producing high quality ductile iron castings is covered, and any attempt to review the pros and cons of the various types of melting furnaces, together with the variables that exist from plant to plant, is beyond the scope of this presentation.

QUALITY CONTROL

Ductile iron, in this application, is produced under license agreement with The International Nickel Co. For quality control, a chill test bar and a chemical analysis coupon are cast with each heat. Determinations are made for silicon, carbon, manganese, nickel and magnesium for every heat. Microscopic examination generally is at random, but specific, for heats low in magnesium or otherwise off-color.

The chill test bar is fractured, and by daily comparison gives the first indication of any trend from the normal or the possibility of an off-colored heat. Originally, mechanical properties were determined from keel bars cast with each heat. However, after sufficient data had been accumulated, and because of the high cost of keel bars, these were reduced to one keel bar daily for each type of ductile iron produced unless keel bars are specifically required for certifying a particular heat.

Each heat of castings is piled separately and held until it has been approved chemically and structurally by the laboratory. The gates and risers are then removed and the castings heat treated, after which they are spot checked for Brinell hardness. Any heat of castings suspected of being off-color is heat treated separately. This is followed by a thorough Brinell check on the castings after heat treatment.

APPLICATION

In this application, castings are produced from over 600 production and semi-production patterns. Castings range in section size from $\frac{3}{32}$-in. up to 3 in., with the bulk falling between $\frac{1}{4}$-in. and $\frac{5}{16}$-in. Average weight is about 4½ lb. With few exceptions, castings receive some form of heat treatment.

The yield of good castings for the year 1958 averaged 48.2 per cent, with foundry scrap averaging 5 per cent and machine shop scrap running less than 1 per cent. The yield and scrap figures of themselves are not impressive, and no doubt similar castings of less stringent engineering requirements could be produced more economically with other types of melting units. However, these are small, light section castings the main products of which are safety devices, all of which require high engineering standards of workmanship, inspection and quality of materials.

These high standards insure that the parts function properly in protecting the lives of multitudes of people. Because of this, the significance of the methods and controls employed is apparent.

INDIRECT ARC ROCKING FURNACE

Two 1000AA conical shell furnaces and one 750A cylindrical shell furnace are employed in this application. Combined in a 16 hr operation, they have a

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total cold charge melt capacity of 20 tons. The 1000AA furnaces are equipped with 530 kva transformers and have a 400 kw rate of input. The cold charge melting rate for ductile iron will average 20 lb/min or 1200 lb/hr. Power consumption in a 16 hr operation will average 670 kw/ton. Electrode consumption will run 15 to 17 lb/ton.

The furnaces are lined with an outer lining of second quality fire brick and an inner lining of 92 per cent aluminum oxide special refractory shapes. These linings are neutral or slightly basic and fairly impervious to slag attack.

Linings will average 240 tons melt each. However, prior to the use of return scrap in the charge, lining life in the first of this type lining gave 320 tons melt. The sand is not cleaned from the return scrap, and while there is little slag in the furnace, it is highly acid. In time, at the high working temperatures employed, slag takes its toll on the lining. Silicon carbide door bricks are used and they will average 40 to 50 tons melt per brick.

Five conical furnace shells are rotated between the two 1000AA furnaces for refractory maintenance. A shell is removed from the furnace once a week in an 8 hr operation, or twice a week in a 16 hr operation for major patching with a high alumina ramming mix. Daily minor repairs (mostly around the door opening) are done with a hot patch refractory cement. Refractory repair material will run 15 to 20 lb/ton melt.

FURNACE OPERATION

At the start of a day's operation, after minor refractory repairs have been made, the furnace is preheated by applying 200 kw before the metal is charged into the furnace. These furnaces are equipped with automatic electrode feed and rocking controls. Since no refining or slagging operations are carried out, the operation is simply one of bringing the temperature of the metal up to between 2930 and 2950 F before tapping.

These furnaces perform best and most efficiently when operated at their full rated capacity. Carbon control is generally uniform. However, carbon content of the metal can vary considerably at times, depending on the arc characteristics of the furnace. The arc conditions occurring within the furnace are best described as a normal or neutral arc, midway between a smokey reducing arc and a sharp oxidizing arc.

A normal arc prevails after the heat is under way, the kilowatt input is at full rated capacity, and the electrode feed control maintains a steady arc gap that gives a slight carbon haze or protective reducing atmosphere in the furnace.

High Temperature Oxidizing

While a sharp arc of itself is not oxidizing in a true sense, the atmosphere in the furnace is clear and free of the protective carbon haze. It is while under this condition at high temperature that silicon, manganese and carbon are oxidized from the metal. The degree of refinement in breaking up and dispersing graphitic carbon being carried to the point where the metal is in an oxidized condition. Primary carbide formation is increased, with the result that the subsequent inoculation of ferrosilicon (after the magnesium treatment) cannot break down the carbide completely.

A smokey or reducing arc prevails when the rate of electrode feed provides only a narrow gap between the electrodes. This may be caused by a drop in the line voltage. In extreme cases, the metal is saturated with carbon, and at times silicon is reduced from the slag making it difficult to have all the carbon dispersed and not in the graphitic form. The carbon equivalent moves too far to the right lessening the carbide forming propensity of the magnesium.

Carbon Saturation

In mild cases of carbon saturation, more magnesium will be required to produce spheroidal structures free of flake graphite. However, in heavy, isolated sections black patches of dendritic or internal shrinkage cavities will be evident.

In extreme cases of carbon saturation where the metal, on solidifying, tries to free itself of the excess carbon as in kishing, the fracture of the castings will show a black banded structure in the cope surface. Microscopic examination of this structure will show a much greater proportion of spheroids than the metal beneath the banded area as evidence of the kishing action. On closer examination, these spheroids appear as if they had exploded. Actually, they are breaking down to graphitic carbon.

The chill test bar fractures of the base metal, the treated metal and the final inoculated metal will give indications of variation in carbon and the conditions under which the metal is melted.

CONTROL OF CHEMISTRY

All the metal is cold-charge melted, and since no slagging or refining operations are carried out control of chemistry is comparatively simple. It begins with the selection of materials used in the base metal charge.

Selected intermediate low phosphorus pig iron is used, and every car of pig iron received is analyzed by the laboratory and piled separately. One or two test heats are run to qualify the pig iron and to check the analysis of the charge before regular consumption of the car of pig iron begins. The tentative purchase specification for pig iron which must be low in subversive elements is as follows:

Silicon, %	0.50 to 0.75
Manganese, % max	0.30
Phosphorus, % max	0.04
Sulfur, % max	0.03
Titanium, % max	0.05

The working range in carbon is between 3.70 per cent and 3.90 per cent in the ferritic type, and between 3.60 per cent and 3.80 per cent for the pearlitic-type ductile irons. Variation in carbon occurs by gradual increase or decrease of carbon in the return scrap, and by variation in carbon from car to car of pig iron. These variations are controlled by adjusting the base metal charge.

Tables 1 and 2 show the breakdown of metal charges for ferritic and pearlitic ductile iron.

The third variation in carbon occurs and is controlled within the furnace itself. Accurate carbon determinations are important, and they are only reliable when using a chilled sample.

PLUNGER LADLE

When the metal in the furnace is ready to tap the treating ladle is brought into position in front of the furnace, and a small quantity of metal is tapped in order to check the temperature with an optical pyrometer. If the temperature is 2930 F or over, the entire

charge is tapped into the treating ladle, at which time the lanthanum-cerium alloy is added, and the ladle is skimmed of slag.

The magnesium alloy plunger is brought into position over the treating ladle, and when the temperature of the metal in the treating ladle is 2820 F the plunger containing the magnesium alloy is lowered into the treating ladle (for light sections, 3/32-in. to 3/16-in., the magnesium alloy is plunged at temperatures up to 2880 F). After 45 sec have elapsed, the plunger is withdrawn, the ladle is again skimmed of slag, and the treated metal is split into two teapot pouring ladles with each getting an inoculation of the 85 per cent ferrosilicon.

Factors of importance to the ferrosilicon inoculation are as follows:

1) The ferrosilicon should contain about 0.75 per cent calcium and about 1.25 per cent aluminum. Metallurgical grades of ferrosilicon not containing these elements in appreciable amounts have little inoculating power.
2) The ferrosilicon should be fed gradually into the stream of metal as it is being transferred from the treating ladle to the pouring ladle.
3) The inoculation should be 0.75 per cent or more silicon.
4) The particle size of the ferrosilicon is also considered to be of importance, and in this application the 3/8-in. by 12 mesh size is used.

Treatment Ladle

The treating ladle is an ordinary foundry ladle to which seven or eight inches have been added to its height. The ladle has no pouring lip and is used only for treating the metal. The ladle has an outer lining of split fire brick and an inner lining of a rammed refractory of the type used in mixing or forehearth ladles. A gage is provided the workmen as it is important to maintain the inner dimensions of the ladle. It is also important that both the treating and pouring ladles be preheated to a cherry red heat or hotter while in use.

The plunger hood assembly weighs 3250 lb, or twice the weight of the metal treated. With proper maintenance of the inside ladle dimensions, including the top edge of the ladle and the refractory surface in the plunger hood, the fumes and flare of the magnesium are practically eliminated. The efficiency, measured in terms of magnesium retained, is good when compared with the open-ladle method. With treating temperatures of 2820 to 2850 F, 50 to 55 per cent of the available magnesium in the plunger is retained in the metal.

The metal has less dross and oxide inclusions and is more fluid than metal treated in the open ladle. The result is that castings from the plunger ladle can be poured at lower temperatures before defects such as misruns, pin holes, and slag inclusions occur.

Plunger Cup

The plunger ladle and hood assembly are simple and economical to construct and will last as long as an ordinary foundry ladle. The weak link is the inverted refractory plunger cup. It costs about 16 dollars, and will last for about 30 immersions. The refractory sleeve costs eight dollars and will last from 90 to 120 immersions. The steel rod, washer, spring and nut cost about three dollars and will give about six months of service.

TABLE 1 — FERRITIC DUCTILE IRON CHARGE

	Pounds		Per Cent
Intermediate low phosphorus pig iron	850	or	53.125
Ductile iron return scrap	640	or	40.000
Boiler plate steel scrap	81¼	or	5.110
Alloy (30% lanthanum - 45% cerium)	¼	or	0.015
Calcium bearing 85% ferrosilicon	14	or	0.875
No. 2 alloy (Ni-Mg-Si)	14	or	0.875
Total charge	1600	or	100.0

TABLE 2 — PEARLITIC DUCTILE IRON CHARGE

	Pounds		Per Cent
Intermediate low phosphorus pig iron	830	or	51.875
Ductile iron return scrap	640	or	40.000
Boiler plate steel scrap	81¼	or	5.110
Spiegeleisen (20% Mn)	20	or	1.250
Alloy (30% lanthanum - 45% cerium)	¼	or	0.015
No. 2 alloy (Ni-Mg-Si)	14	or	0.875
Calcium bearing 85% ferrosilicon	14	or	0.875
Total charge	1600	or	100.0

An expendable metal can containing the alloy is used with each heat. Various types of cans and gage thicknesses have been tried, and it was found that with thinner than 24 gage, the reaction takes place before the plunger hood seats itself. When the can is thicker than 24 gage, the reaction is delayed and spontaneously more violent.

At the present time, it is costing us about 67 cents for the plunger and 53 cents for the can; or a plunger cost of a little more than one dollar for each treatment. The author's company realizes this cost is too high and is trying hard to reduce it. Nevertheless, the cost is tolerable in view of the overall savings affected by this method of treatment.

From a treating temperature of 2820 F, the temperature will drop to 2650-2670 F for the first molds cast from the pouring ladles. The temperature drop in the pouring ladles will average 20 degrees/min, and the last molds cast from these 800 lb ladles will be around 2520 to 2540 F.

RETURN SCRAP

Prior to 1958, with the open-ladle method of treatment (because of the buildup of silicon), practically all the ductile iron return scrap was used in the makeup of cupola gray iron charges. For the entire year of 1958, 40 per cent ductile iron return scrap was used in the ductile iron charges. More than 40 per cent returns could be used if necessary, but 40 per cent returns seems to be a stable amount for this practice.

For better chemical control, two return scrap piles are worked. Current gates, risers, etc., are accumulated on one pile, while return scrap for the charges is used from the older or second pile.

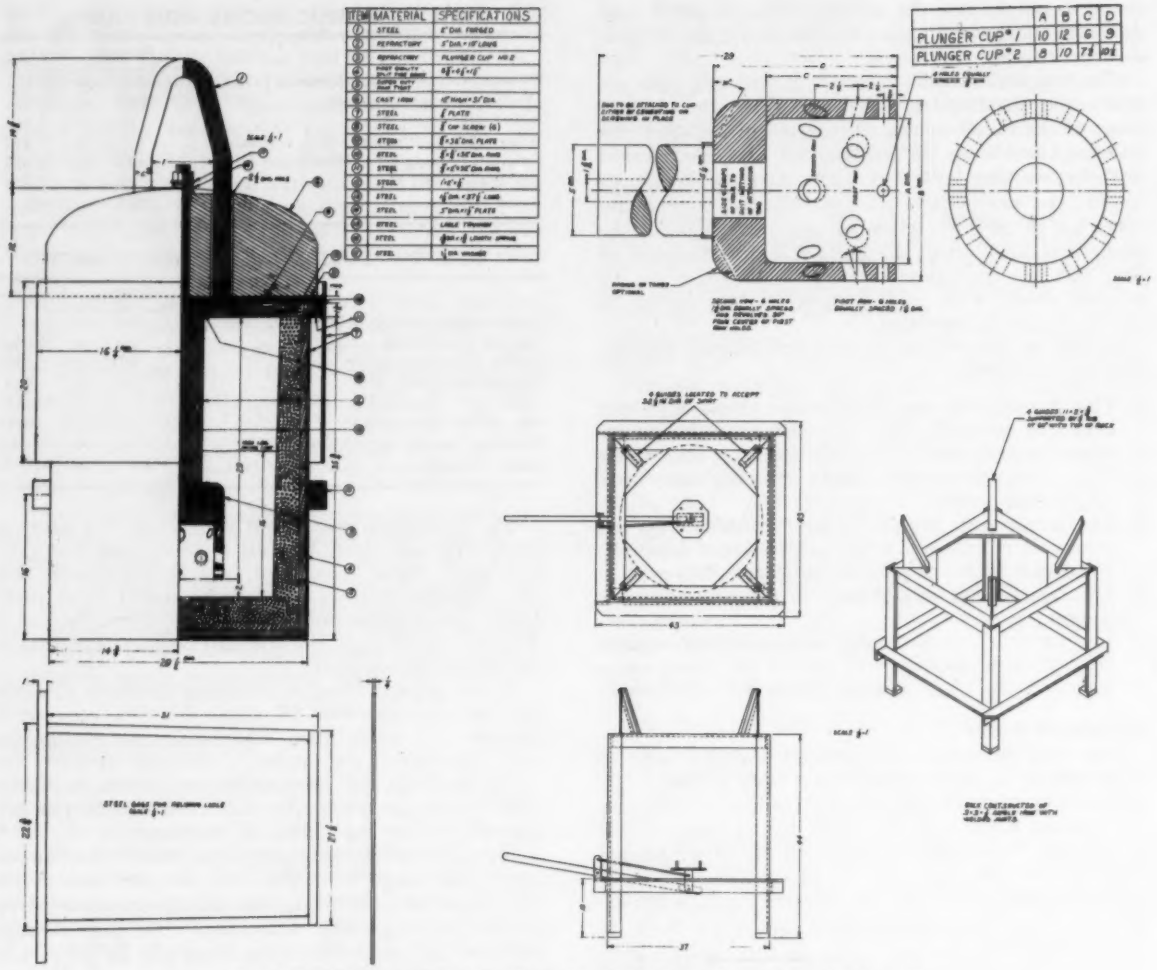
During the year 1958 there were 1751 plunger ladle heats of ductile iron made.

Heats 78 and 745 were rejected due to the presence of flake graphite.

Heat 919 was rejected due to a mixup where the magnesium alloy for a 900 lb heat was used to treat a 1600 lb heat.

Heat 1529, being an experimental one which did not pan out, was rejected.

Table 3 shows the tabulation breakdowns of the 1751 plunger heats in which both chemical and physical tests were taken.



Detail drawing of magnesium alloy plunger ladle used in the production of ductile iron in the indirect arc electric furnace, as described by the author.

TABLE 3 — PLUNGER LADLE HEATS

Date	Heat No.	Composition, % Si	T.C.	Mn	Ni	Mg	Tensile, psi	Yield, psi	Elong., % in 2 in.	Bhn
ANNEALED FERRITIC DUCTILE IRON										
1957										
12-26	20	2.48	3.87	0.26	0.79	0.059	66,000	52,500	21.0	174
12-26	21	2.69	3.75	0.23	0.74	0.054	67,000	53,750	21.0	174
12-26	22	2.46	3.80	0.23	0.76	0.064	65,750	53,125	21.0	170
12-27	23	2.51	3.74	0.23	0.78	0.063	66,250	53,125	21.0	170
12-27	24	2.51	3.77	0.25	0.74	0.059	65,000	51,875	21.0	174
12-30	25	2.48	3.75	0.21	0.73	0.063	63,250	49,375	21.0	163
12-30	26	2.35	3.77	0.22	0.70	0.059	62,750	49,375	22.0	163
12-30	27	2.51	3.70	0.22	0.71	0.063	62,500	48,750	22.0	163
12-31	28	2.69	3.68	0.20	0.75	0.061	66,500	53,750	20.5	170
12-31	29	2.72	—	0.24	0.72	0.051	66,750	53,250	20.5	170
1958										
1-2	30	2.51	3.76	0.22	0.76	0.059	66,750	54,250	21.0	170
1-3	31	2.42	3.74	0.22	0.76	0.064	64,000	45,000	25.0	163
1-3	32	2.45	3.80	0.24	0.73	0.062	64,500	47,000	25.0	163
1-3	33	2.34	3.84	0.22	0.75	0.067	64,750	47,500	25.0	170
1-6	34	2.51	3.80	0.20	0.76	0.055	65,000	50,000	24.0	170
1-6	35	2.45	3.71	0.22	0.72	0.062	64,500	50,000	24.0	166
1-6	36	2.45	3.73	0.20	0.73	0.062	65,000	50,000	25.0	166
1-8	41	2.66	3.83	0.20	0.76	0.061	67,250	51,000	23.0	174
1-8	42	2.54	3.82	0.20	0.77	0.059	65,750	51,000	22.0	170
1-8	43	2.62	3.82	0.20	0.80	0.057	64,250	49,750	23.0	163
1-9	44	2.54	3.84	0.25	0.76	0.065	65,000	49,500	23.0	163

(Continued on next page)

TABLE 3 (continued) — PLUNGER LADLE HEATS

Date	Heat No.	Composition, %					Tensile, psi	Yield, psi	Elong., % in 2 in.	Bhn
		Si	T.C.	Mn	Ni	Mg				
1958										
1-10	48	2.35	3.86	0.20	—	0.051	62,250	47,500	23.0	163
1-15	57	2.46	3.74	0.22	0.82	0.066	68,500	53,000	21.5	179
1-16	64	2.45	3.74	0.22	0.72	0.051	65,250	50,000	23.0	170
1-29	102	2.42	3.74	0.19	0.53	0.039	60,000	48,000	19.0	149
1-29	103	2.48	3.73	0.20	0.76	0.051	64,250	51,000	24.0	163
1-30	110	2.45	3.79	0.19	0.73	0.045	63,500	50,000	25.0	159
1-31	117	2.54	—	0.20	0.75	0.049	64,000	50,000	23.0	166
2-3	128	2.45	3.79	0.20	0.76	0.050	64,500	51,250	24.0	163
2-4	137	2.54	3.77	0.22	0.77	0.053	64,500	50,500	22.5	159
2-5	162	2.58	3.84	0.20	0.73	0.050	63,750	48,500	24.0	166
2-7	178	2.62	3.81	0.22	0.72	0.052	64,000	50,000	23.5	170
2-10	191	2.29	3.74	0.22	0.77	0.056	64,000	49,000	23.5	166
2-17	234	2.23	3.73	0.19	0.73	0.050	61,000	47,000	24.0	159
2-18	243	2.16	3.82	0.19	0.72	0.047	61,000	46,250	24.0	163
2-19	255	2.19	3.83	0.20	0.72	0.054	61,250	45,750	25.5	163
2-24	289	2.35	3.76	0.19	0.76	0.051	62,000	46,250	24.0	156
2-26	319	2.35	3.85	0.20	0.78	0.054	62,500	47,500	25.0	163
2-26	325	2.51	—	0.20	0.79	0.045	63,250	49,500	24.0	166
2-27	340	2.58	3.68	0.20	0.81	0.050	63,500	49,500	23.5	166
3-3	368	2.16	3.52	0.22	0.74	0.045	59,750	46,000	22.0	156
3-3	371	2.51	—	0.19	0.80	0.052	62,750	—	23.5	163
3-4	387	2.62	3.70	0.20	0.80	0.049	65,250	51,500	22.5	170
3-5	405	2.58	—	0.19	0.84	0.059	62,000	47,500	22.5	163
3-6	418	2.48	3.73	0.19	0.81	0.056	64,250	51,500	22.5	170
3-7	434	2.39	—	0.22	0.77	0.060	64,250	52,500	22.5	159
3-13	488	2.32	3.76	0.23	0.77	0.056	66,250	50,625	22.0	170
3-17	528	2.39	—	0.20	0.78	0.054	64,500	50,000	22.5	163
4-23	883	2.42	3.72	0.22	0.82	0.057	62,500	48,500	21.0	166
4-28	914	2.42	—	0.20	0.46	0.050	63,000	48,500	24.0	166
5-26	1011	2.66	3.73	0.20	0.85	0.064	64,000	51,000	23.0	163
5-27	1015	2.42	3.70	0.38	0.83	0.058	64,750	48,125	25.0	156
7-11	1165	2.48	3.70	0.27	0.84	0.059	67,000	54,000	22.5	174
8-19	1210	2.83	—	0.19	0.83	0.043	67,000	52,500	16.0	179
8-21	1229	2.45	—	0.22	0.82	0.056	67,750	51,250	23.5	174
8-22	1238	2.54	3.75	0.22	0.88	0.059	66,000	51,250	24.5	170
8-22	1243	2.51	3.62	0.22	0.89	0.072	66,750	52,000	23.0	170
9-2	1244	2.66	—	0.22	0.86	0.059	67,750	52,500	23.0	174
9-3	1250	2.54	—	0.23	0.86	0.058	67,000	50,000	23.0	166
9-14	1276	2.32	3.57	0.20	0.90	0.069	64,750	46,250	22.5	163
9-15	1277	2.58	3.77	0.23	0.84	0.049	67,250	51,250	22.5	163
9-16	1284	2.45	3.67	0.20	0.83	0.060	66,500	52,500	22.5	179
9-16	1289	2.42	3.69	0.22	0.81	0.052	65,250	51,250	22.0	163
9-17	1294	2.54	3.79	0.22	0.84	0.064	65,250	50,000	23.0	166
9-19	1313	2.62	3.71	0.22	0.86	0.060	72,000	51,875	23.0	174
9-19	1321	2.45	—	0.20	0.84	0.061	66,750	50,625	22.5	174
9-29	1325	2.69	—	0.20	0.84	0.069	65,250	50,000	22.5	170
10-1	1335	2.79	—	0.22	0.81	0.066	66,500	51,250	22.5	166
10-1	1341	2.48	—	0.19	0.82	0.052	65,500	51,250	24.0	170
10-2	1343	2.72	—	0.23	0.82	0.066	67,000	50,000	23.0	163
10-13	1356	2.45	—	0.23	0.86	0.064	65,250	50,000	23.0	163
10-14	1363	2.62	—	0.20	0.84	0.076	65,500	50,625	24.5	163
10-14	1371	2.54	3.75	0.22	0.84	0.068	67,750	52,500	23.0	170
10-15	1374	2.62	3.75	0.19	0.84	0.059	65,250	50,000	23.0	163
10-16	1383	2.82	—	0.20	0.84	0.066	65,000	50,000	24.0	163
10-16	1389	2.48	—	0.23	0.86	0.077	66,000	51,875	24.0	166
10-17	1393	2.48	3.76	0.23	0.82	0.073	65,000	50,000	25.0	159
10-17	1399	2.66	—	0.23	0.84	0.071	66,750	51,875	24.5	163
10-20	1404	2.58	—	0.23	0.84	0.073	66,500	50,625	25.5	163
10-21	1411	2.58	—	0.22	0.83	0.063	65,500	50,000	24.0	159
10-24	1432	2.66	3.72	0.23	0.82	0.062	65,000	48,750	23.0	163
10-27	1434	2.45	—	0.22	0.82	0.074	65,750	50,000	24.0	163
10-28	1446	2.58	—	0.22	0.80	0.051	65,750	52,500	24.0	163
10-30	1457	2.79	—	0.20	0.82	0.065	66,750	52,500	24.0	163
10-31	1464	2.72	—	0.22	0.82	0.070	64,500	50,000	24.0	163
11-3	1472	2.72	—	0.20	0.82	0.056	65,750	50,000	24.0	156
11-4	1480	2.48	—	0.22	0.84	0.071	72,200	50,000	23.0	163
11-5	1483	2.69	—	0.24	0.81	0.070	66,500	50,500	25.0	179
11-6	1491	2.72	—	0.22	0.82	0.066	66,600	50,500	23.0	163
11-7	1500	2.48	—	0.23	0.81	0.064	66,100	50,000	23.0	170
11-7	1502	2.26	3.76	0.25	0.61	0.074	62,000	45,000	25.0	163

(Continued on next page)

TABLE 3 (continued) — PLUNGER LADLE HEATS

Date	Heat No.	Composition, % Si	T.C.	Mn	Ni	Mg	Tensile, psi	Yield, psi	Elong., % in 2 in.	Bhn
1958										
11-10	1509	2.29	3.61	0.20	0.79	0.050	63,100	47,000	22.5	149
11-11	1517	2.58	—	0.23	0.79	0.070	65,600	50,000	23.5	156
11-13	1532	2.39	—	0.20	0.78	0.063	65,000	48,000	24.0	149
11-13	1541	2.32	—	0.20	0.81	0.072	65,000	48,500	24.0	156
11-14	1543	2.62	—	0.22	0.81	0.061	65,300	50,500	23.5	163
11-17	1557	2.58	—	0.20	0.81	0.057	65,250	47,500	25.0	156
11-18	1566	2.51	—	0.22	0.80	0.056	66,500	48,750	22.5	163
11-18	1569	2.39	—	0.20	0.81	0.061	63,500	46,250	23.0	163
11-20	1581	2.69	—	0.22	0.80	0.061	65,750	47,500	24.0	163
11-21	1590	2.42	—	0.23	0.79	0.065	66,000	48,750	23.0	163
11-25	1607	2.58	3.77	0.19	0.82	0.058	68,250	51,250	24.0	170
11-25	1614	2.58	3.70	0.20	0.81	0.059	66,000	47,500	24.0	163
11-26	1626	2.26	—	0.20	0.81	0.070	63,750	45,000	25.0	149
11-28	1634	2.42	—	0.19	0.82	0.070	64,750	47,500	23.5	163
11-28	1641	2.39	—	0.19	0.84	0.075	64,000	46,250	23.0	156
12-3	1651	2.58	—	0.22	0.86	0.071	65,000	46,250	22.5	163
12-4	1654	2.42	—	0.20	0.76	0.060	65,500	47,500	24.0	156
12-5	1660	2.39	—	0.22	0.80	0.059	66,750	50,000	24.0	170
12-8	1667	2.39	—	0.18	0.81	0.066	65,000	47,500	24.0	160
12-9	1678	2.39	—	0.20	0.83	0.063	64,600	45,500	23.5	156
12-10	1683	2.35	3.73	0.20	0.81	0.066	66,000	47,500	22.0	159
12-11	1690	2.51	3.68	0.22	0.82	0.072	65,750	47,500	23.5	163
12-12	1697	2.32	3.70	0.22	0.77	0.064	63,500	46,250	23.5	156
12-15	1706	2.48	3.79	0.20	0.80	0.060	68,000	47,500	21.0	159
12-16	1717	2.32	—	0.20	0.81	0.069	65,500	46,500	22.5	156
12-17	1723	2.42	3.70	0.22	0.80	0.063	66,500	49,375	23.5	159
12-18	1730	2.42	3.70	0.25	0.76	0.063	67,500	51,875	23.5	166
12-19	1742	2.42	3.69	0.20	0.81	0.063	65,000	48,000	24.0	159
12-19	1747	2.35	—	0.22	0.81	0.065	64,300	46,000	23.5	156
12-22	1751	2.39	—	0.22	0.81	0.065	65,200	48,000	25.0	163
12-22	1757	2.42	3.74	0.20	0.84	0.066	64,600	47,000	23.0	156
12-23	1762	2.35	—	0.20	0.81	0.066	61,250	45,000	—	156
12-24	1767	2.35	3.74	0.22	0.76	0.059	61,000	53,250	—	153
AS-CAST FERRITIC DUCTILE IRON										
1958										
2-17	234	2.23	3.73	0.19	0.73	0.050	76,750	56,250	14.5	187
11-7	1502	2.26	3.76	0.25	0.61	0.074	71,500	50,500	15.0	174
NORMALIZED AND DRAWN PEARLITIC DUCTILE IRON										
1958										
2-13	215	2.23	3.75	0.47	0.75	0.053	136,250	93,000	4.5	286
2-20	274	2.23	3.92	0.37	0.73	0.059	123,500	93,500	3.5	286
2-21	282	2.42	3.89	0.40	0.76	0.060	133,500	87,000	6.0	269
2-25	297	2.26	3.62	0.38	0.79	0.047	124,250	83,750	5.0	255
2-27	337	2.29	3.84	0.37	0.81	0.056	132,500	88,500	6.0	269
2-28	351	2.35	3.64	0.41	0.81	0.057	134,000	94,250	5.0	277
3-4	383	2.39	—	0.25	0.78	0.057	133,500	88,000	5.5	286
3-5	400	2.35	3.72	0.38	0.78	0.059	133,250	86,500	6.0	286
3-6	415	2.42	3.79	0.39	0.77	0.058	132,750	86,500	5.0	286
3-7	427	2.48	—	0.44	0.77	0.062	133,250	85,500	6.0	302
3-10	447	2.54	3.86	0.45	0.77	0.059	133,000	89,000	4.5	286
3-11	463	2.39	3.71	0.41	0.77	0.059	126,500	82,500	6.0	286
3-12	472	2.39	3.60	0.40	0.80	0.060	128,500	82,500	5.0	286
3-14	509	2.45	3.78	0.37	0.77	0.059	135,000	88,000	5.0	286
3-17	523	2.45	3.69	0.37	0.77	0.059	132,500	83,500	5.0	286
3-19	555	2.45	—	0.40	0.84	0.066	129,750	91,250	4.0	286
3-20	569	2.45	3.82	0.40	0.81	0.064	136,500	92,500	6.0	286
3-21	588	2.42	3.58	0.37	0.80	0.059	131,750	84,125	5.0	286
3-24	603	2.39	—	0.37	0.84	0.054	135,000	88,750	6.5	286
3-25	617	2.51	—	0.45	0.83	0.060	136,750	92,500	4.5	286
3-26	631	2.54	—	0.43	0.83	0.064	132,000	91,250	4.0	286
3-26	634	2.58	—	0.38	0.93	0.068	132,000	73,500	6.5	286
3-31	661	2.45	3.52	0.31	0.84	0.056	127,500	85,000	5.0	269
4-1	675	2.29	3.50	0.35	0.84	0.054	130,250	78,750	6.0	—
4-2	680	2.51	3.86	0.43	0.78	0.061	135,500	93,000	6.0	286
4-8	721	2.48	3.67	0.38	0.81	0.059	138,500	95,000	4.5	293
4-10	757	2.35	3.62	0.41	0.80	0.062	126,500	88,750	6.0	269
4-11	774	2.39	3.60	0.40	0.83	0.052	132,500	88,000	6.0	286

(Continued on next page)

TABLE 3 (continued) — PLUNGER LADLE HEATS

Date	Heat No.	Composition, % Si	T.C.	Mn	Ni	Mg	Tensile, psi	Yield, psi	Elong., % in 2 in.	Bhn
1958										
4-14	788	2.51	3.68	0.41	0.83	0.048	130,500	85,500	6.0	269
4-15	808	2.51	—	0.40	0.80	0.056	131,000	86,000	6.0	286
4-16	811	2.29	3.45	0.34	0.83	0.061	125,500	81,500	5.0	277
4-17	832	2.32	3.69	0.40	0.81	0.059	126,000	80,500	6.0	269
4-18	848	2.32	3.57	0.18	0.81	0.045	125,650	84,000	5.0	277
4-21	863	2.35	3.61	0.37	0.81	0.050	130,000	90,500	5.0	286
4-25	899	2.35	—	0.19	0.86	0.055	129,000	85,000	6.0	269
4-29	921	2.54	3.53	0.40	0.83	0.054	134,000	90,000	4.0	286
5-1	939	2.32	3.65	0.40	0.82	0.057	123,500	85,000	4.0	286
5-12	960	2.42	—	0.41	0.82	0.066	122,750	81,500	4.5	269
5-13	967	2.64	3.84	0.46	0.86	0.067	130,000	90,600	4.0	286
5-14	979	2.58	3.49	0.41	0.83	0.059	132,000	92,500	4.5	302
5-20	999	2.45	3.48	0.44	0.84	0.058	135,000	88,750	6.0	286
5-21	1001	2.29	3.62	0.43	0.80	0.051	131,000	83,750	5.0	255
5-22	1004	2.45	3.49	0.30	0.82	0.058	125,000	76,875	5.0	269
5-26	1006	2.45	3.53	0.40	0.86	0.068	126,000	83,125	6.0	269
5-29	1032	2.39	3.67	0.38	0.81	0.057	124,000	85,000	4.5	269
6-9	1045	2.54	—	0.44	0.82	0.058	130,000	90,000	6.0	269
6-10	1059	2.72	3.82	0.46	0.88	0.057	126,750	93,125	5.0	269
6-11	1069	2.32	3.53	0.38	0.85	0.070	124,500	80,625	4.0	277
6-12	1078	2.32	—	0.41	0.81	0.063	120,000	85,000	3.5	277
6-24	1108	2.58	—	0.46	0.82	0.060	126,750	84,375	6.0	269
6-25	1118	2.45	—	0.41	0.84	0.071	126,750	85,000	5.0	286
6-30	1127	2.26	3.77	0.41	0.75	0.057	126,750	85,000	6.0	269
7-10	1154	2.45	3.72	0.38	0.80	0.066	121,750	81,250	6.0	269
7-11	1170	2.48	3.74	0.49	0.83	0.059	124,000	77,000	6.5	255
9-18	1302	2.76	—	0.43	0.86	0.060	137,500	86,875	5.5	286
9-30	1329	2.79	—	0.43	0.82	0.061	130,000	76,250	6.0	269
10-2	1344	2.66	3.74	0.46	0.81	0.059	130,750	78,750	6.0	277
10-15	1381	2.39	—	0.37	0.84	0.077	130,000	81,250	8.0	286
10-22	1415	2.76	—	0.43	0.84	0.066	132,000	85,000	7.0	286
10-23	1425	2.58	—	0.50	0.82	0.065	129,500	86,250	5.5	302
10-29	1451	2.32	3.72	0.41	0.81	0.075	119,250	68,750	6.5	262
11-11	1510	2.79	3.69	0.46	0.82	0.061	132,000	81,250	6.5	286
11-14	1552	2.39	—	0.41	0.79	0.061	121,500	70,000	6.5	255
11-19	1572	2.58	—	0.46	0.79	0.058	128,750	77,500	6.5	269
11-24	1598	2.54	3.75	0.41	0.78	0.057	128,000	77,500	7.0	269
11-24	1606	2.39	—	0.40	0.80	0.065	125,500	75,000	6.5	262
11-26	1619	2.45	3.67	0.44	0.82	0.059	125,000	77,500	6.5	269
12-18	1739	2.29	—	0.40	0.79	0.068	127,500	75,625	7.5	255
2-12	194	2.39	3.76	0.43	0.77	0.061	121,000	79,000	8.0	248
3-27	640	2.51	3.73	0.44	0.81	0.066	116,750	67,625	7.0	223
6-23	1096	2.42	3.79	0.41	0.73	0.061	111,250	72,250	9.0	235
6-23	1097	2.32	—	0.38	0.81	0.064	116,000	75,000	8.5	248
6-26	1122	2.42	—	0.40	0.81	0.070	119,000	76,500	7.5	262
7-7	1136	2.42	3.63	0.41	0.81	0.058	112,500	75,000	8.0	269
7-8	1143	2.62	3.58	0.44	0.91	0.061	119,250	79,000	8.0	269
7-9	1152	2.54	3.76	0.51	0.82	0.067	94,250	68,750	12.0	235
7-22	1181	2.58	3.79	0.49	0.88	0.061	98,500	71,000	10.0	235
7-22	1190	2.35	—	0.40	0.84	0.066	101,000	69,000	10.5	228
7-24	1193	2.45	3.62	0.51	0.94	0.050	102,750	75,000	8.0	235
AS-CAST PEARLITIC DUCTILE IRON										
1958										
2-13	215	2.23	3.75	0.47	0.75	0.053	86,500	59,000	11.0	202
2-14	228	2.32	3.79	0.51	0.75	0.058	87,500	59,000	11.0	207
2-27	334	2.29	3.84	0.37	0.81	0.056	81,500	58,500	10.0	179
2-28	351	2.35	3.64	0.41	0.81	0.057	84,500	61,500	12.0	187
5-2	950	2.35	3.60	0.38	0.81	0.063	78,500	58,000	12.0	187

CONCLUSIONS

The indirect arc rocking furnace is of small capacity and rather slow for melting ferrous metals. Because of its design, it does not lend itself to refining or slagging operations.

This type of furnace lacks the electro-dynamic stirring action of the induction and direct arc furnace, therefore, higher initial temperatures must be attained in order to break down or dissolve graphitic carbon in the base iron prior to the magnesium treatment.

Special refractory shapes are required to line the furnace, and only the better grades of refractories can withstand the high temperatures employed. This severe application, together with limited capacity and melting rate, adds up to high refractory costs.

Indirect Arc Furnace

The advantages of the indirect arc rocking furnace lie in its simplicity of operation and its ability to

TABLE 4 — CHEMICAL AND MECHANICAL PROPERTIES

Typical Chemical Composition	Ferritic Ductile, %	Pearlitic Ductile, %
Total carbon	3.80	3.80
Silicon	2.40	2.40
Manganese	0.20	0.40
Phosphorus	0.03	0.03
Magnesium	0.06	0.06
Nickel	0.70	0.70

The mechanical properties after suitable heat treatment are determined on tensile bars from 1 in. keel bars.

	Ferritic Ductile Annealed	Pearlitic Ductile Normalized and Drawn	
		1200 F Draw	1100 F Draw
Tensile strength psi, min.	60,000	80,000	100,000
Yield strength psi, min.	45,000	60,000	70,000
Elong. in 2 in., % min.	15	8	4
Brinell hardness, max.	179	235	277

handle a large variety of ferrous and nonferrous metals. Its performance in consistency and quality is in proportion to the amount of control exercised in its application.

The magnesium alloy plunger ladle was introduced to the ductile iron licensees in the United States by The International Nickel Co. While its use in this country is comparatively new, it will be only a matter of time until refractory or ceramic manufacturers overcome its one apparent drawback of low service life of the plunger cup.

Plunger Ladle Advantages

The advantages of the plunger ladle are not limited to an electric furnace operation, but may be utilized equally as well in cupola production of ductile iron with the added advantage that the need for a forehearth in front of the cupola, with its loss of 30 to 70 or more degrees of temperature, is eliminated.

ACID CUPOLA MELTING FOR DUCTILE IRON

By H. E. Henderson

ABSTRACT

The method of manufacture of ductile iron in the acid cupola used at the author's company is given. The various phases of this procedure including carbon pick-up, ladle addition, composition control and stabilizing elements are given. Tests which were conducted in the basic cupola are also dealt with, giving the company's results of these tests.

INTRODUCTION

The author's company was one of the first foundries to begin production of ductile iron; in 1949 production began. Production was begun as in most other foundries at that time, with an acid cupola, high pig iron charge and desulfurizing with soda ash to 0.05 to 0.06 per cent sulfur. The treatment for converting to ductile iron consisted of about 2.5 per cent of no. 2 nickel magnesium alloy or 0.38 per cent magnesium added, with a late addition of 75 per cent ferrosilicon.

With this procedure there was trouble, either with castings which were nonmachinable or with castings having low physical properties. Also, the castings showed sulfide slag inclusions (one form of cope defect). It was difficult to maintain pouring temperatures high enough to prevent pinholes (another form of cope defect) in the castings. In addition to this, the cost of the charge and the alloy was excessive.

The next approach used was with the basic water-cooled cupola, which was put into operation in Feb. 1951. By using a basic slag, we found it possible to produce a low sulfur base iron with an economical charge containing a high percentage of steel scrap. However, it was found difficult to maintain a constant analysis of silicon, carbon and manganese with the basic operation. In order to maintain the sulfur below 0.02 per cent, which was desired for ductile iron, the carbon content was over 4.0 per cent and carbon segregation in the castings was experienced (still another form of cope defect).

This would show up as a dapple grey appearance on the machined surface of the cope side of the casting. There was also a noted difference in the hardness of cope and drag, and the carbon content would vary from 3.40 per cent in the drag to over 6.0 per cent in the cope. Due to these circumstances, and the unavailability of enough steel scrap sufficiently free of tramp elements in the area, basic melting was discontinued.

At this time work was begun with the Air Reduction Co. on the injection of calcium carbide for desulfurization. It was found possible to make ductile iron with much less magnesium alloy, by treating after desulfurizing with calcium carbide to less than 0.02 per cent sulfur.

Carbide Desulfurizing

This procedure requires an addition of 1.0 to 1.5 per cent calcium carbide, a sizeable cold addition of alloy, which means that the iron must be melted at a high temperature. Further, the efficiency of the carbide desulfurizing reaction increases rapidly with higher temperatures. These tests indicated that the metal must melt at 2900 F min., and preferably 2950 F for optimum results.

In the Fall of 1952, it was decided to build a shell molding foundry to produce both gray and ductile iron castings. The melting unit was selected to produce iron at maximum temperatures, with calcium carbide desulfurization outside an acid lined cupola, for the manufacture of ductile iron. The cupolas, as shown in Fig. 1, were designed to melt from eight to ten tons/hr at tap temperature above 2950 F, and to operate on alternate days for periods up to 24 hr.

In general appearance, they resemble blast furnaces more than conventional cupolas. The steel shells are 72 in. I.D., and are lined with acid refractories from 48 in. to 56 in. depending on the melting rate desired. Four 5 in. I.D. water-cooled copper tuyeres are used per cupola, giving a tuyere ratio of 4.3 per cent at 48 in. I.D. or 3.4 per cent at 54 in. I.D., and air velocities through the tuyeres up to 20,000 ft/min. The tuyeres protrude beyond the lining a distance of from six to nine in. into the coke bed, and the nose to nose distance is 36 in. between opposing tuyeres.

They slope downward by an angle of 12½ degrees to aid in keeping them clear internally of slag or other foreign materials. The tuyeres are located 36 in.

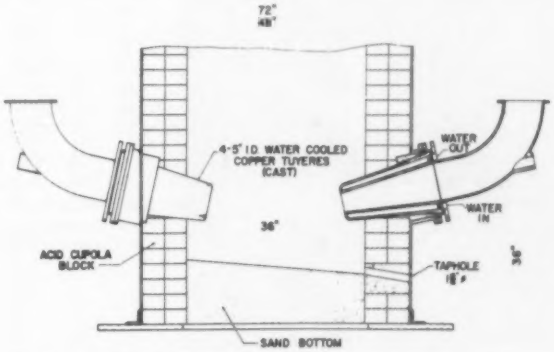


Fig. 1 — Shell mold cupola, details of lower portion.

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Fig. 2 — Excess tuyere cooling water is circulated to a water ring which cools the cupola shell.

above the mandrel plate where they pass through the shell.

The cooling water circuit is automatically controlled by the effluent water temperature and is maintained at 130 F. The excess tuyere cooling water is circulated to a water ring which cools the cupola shell, as shown in Fig. 2.

The blast heater is an independently fired unit using either gas or oil as fuel, and will supply 6700 cfm of blast air at temperatures up to 1000 F. The centrifugal blower is capable of supplying this air at pressures up to 60 oz.

METHOD OF MANUFACTURE

The shell cupolas were placed in operation in July 1954, and have been in continuous operation since that time. It has been found that the company is able to melt for ductile iron continuously at temperatures in the range of 2950 to 3000 F, and reaching a maximum of 3030 F.

Table 1 shows the charge for ductile iron. The 2,000 lb charge consists of 500 lb low carbon, low manganese pig iron; 700 lb selected steel scrap, as free of carbide stabilizing elements and tramp elements as possible; and 800 lb of ductile iron return scrap.

The elements in the charge are 1.02 per cent silicon, 0.32 per cent manganese, 0.054 per cent phosphorus and 2.05 per cent total carbon. The actual average analysis is 1.10 per cent silicon, 0.30 per cent manganese, 0.064 per cent phosphorus and 3.60 per cent total carbon. This shows a silicon gain of 7.3 per cent, a manganese loss of 6.7 per cent, a phosporous gain of 0.01 per cent and a carbon pickup of 1.55 per cent.

TABLE 1 — DUCTILE IRON CHARGE FOR ACID CUPOLA

		Per Cent				Pounds			
Material	Pounds	Si	Mn	P	T.C.	Si	Mn	P	T.C.
Low Mn pig	500	0.10	0.10	0.05	2.00	0.50	0.50	0.25	10.0
Steel	700	0.10	0.50	0.05	0.30	0.70	3.50	0.35	2.1
D.I. return	800	2.40	0.25	0.06	3.60	19.20	2.00	0.48	28.8
Total	2000					20.40	6.00	1.08	40.9
Element in charge						1.02	0.30	0.05	2.05
Ave. actual analysis						1.10	0.30	0.06	3.60
Gain or loss						+0.08	0.0	+0.01	+1.55

Coke, lb/2000 lb	250
Dolomite, lb/2000 lb	30
Air blast, lb-min.	500
Blast temp., F	900
Cupola I.D., in.	56
Bed height, in.	42
Melting rate, ton/hr	14

Carbon Pickup

The carbon pickup as figured by Wally Levi's formula

$$T.C. = 2.40 + \tfrac{1}{2}\,C \text{ in Charge} - \tfrac{1}{4}\,(Si + P)$$

gives an expected carbon of 3.15 per cent. However, if we add 0.20 per cent for the hot blast, 0.15 per cent for the protruding tuyeres and 0.10 per cent from the graphite tubes, we come up with the expected 3.60 per cent total carbon. The coke ratio is 8 to 1 or 250 lb/2000 lb charge of high carbon pickup coke. At a slow melting rate more coke is used, but the company changes to a low carbon pickup coke.

The flux charge is low (only 1.5 per cent) consisting of 30 lb of dolomitic limestone/2000 lb charge. The cupola is charged upon a bed height of coke 42 in. above the tuyeres. The air blast rate is 500 lb of air/min, and the blast temperature is 950 F. The cupola is lined to 56 in. inside diameter and the melting rate is 14 tons/hr.

Figure 3 shows the actual carbide treating basin in operation. The metal flows from the cupola at the left into the front slagging trough where the cupola slag is removed. About 1½ per cent calcium carbide (20 mesh by down) is fed through the two graphite tubes through the cover and injected 12 in. under the surface of the metal at the rate of about four lb of carbide/min through each tube. The dry slag is raked from the surface through the opening in the cover into a water disposal unit.

The graphite tubes are lowered at about 15 min intervals to maintain an immersion depth of 12 in. The calcium carbide is supplied from two 2000 lb capacity feeders located above the treating basin. In these feeders the nitrogen gas fluidizes the carbide, which allows it to be conveyed through a hose to the graphite injection tubes. The sulfur is lowered from 0.085 per cent to 0.015 per cent by this treatment.

Ladle Addition

In Fig. 4 the desulfurized metal is being tapped from the forehearth onto a fixed amount of magnesium alloy (now 0.19 per cent contained magnesium

Fig. 3 — Carbide treating basin in operation.

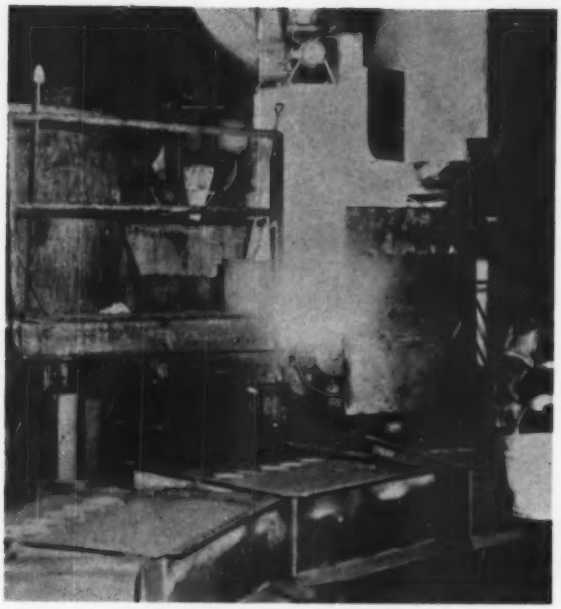

Fig. 4 — The desulfurized metal is tapped from the forehearth onto a fixed amount of magnesium alloy and flux.

in this operation) and flux. After the ladle is one-half full, mischmetal and ferrosilicon plus 0.1 per cent calcium silicon are added and the ladle is filled to the correct weight as shown on an electronic strain gage scale. The metal in the ladle is stirred, slagged, test bars poured and transferred to a pouring ladle to be poured into the shell molds backed with steel shot shown coming to the pour off station.

Figure 5 shows the pouring of the test bars. Two 1-in. keel blocks have been poured and now a 1.2 in. diameter bar, 10 in. long is being poured. In order to be sure the metal will meet specifications a bar is poured from each ladle of iron. By means of controlled cooling, the 1.2 in. bars are tested within 15 min after pouring, and before the castings represented are taken from the mold. The test consists of placing the bars on 8 in. centers and applying a transverse load midway between the centers (Fig. 6).

The load and deflection are recorded, and Brinell hardness tests made. The fracture of the broken bar is examined visually for structure and soundness. If all is in order, and the transverse load and deflection equal or exceed the specified minimum values, the castings represented are released for processing. If the fracture appears to be satisfactory but the breaking load is low, the castings in question are set aside until mechanical properties in the keel block representing these specific castings have been determined. If the fracture of the 1.2 in. bar indicates failure to convert to nodular graphite, all castings represented by it are scrapped. More than 99 per cent of our ductile iron passes this rigid inspection and meets the customer's specification.

CONTROL OF COMPOSITION

It was found, as pointed out before, that in order to make ductile iron with consistent as-cast properties, the composition must be rigidly controlled. Figure 7 shows the variation in physical properties with carbon equivalent. It has been found that for the type of castings the company manufactures the carbon equivalent must be in the range of 4.2 to 4.6. Carbon equivalents less than 4.2 give high Brinell hardness and a tendency to form carbides and excess shrinkage, while those above 4.6 tend to give carbon segregation and low yield strengths.

Figure 8 is a frequency chart for total carbon content. It may be noted that 85 per cent of the carbons fall within the range of 3.50 to 3.70 per cent, and 99 per cent within the range of 3.40 to 3.80 per cent total carbon. The carbon analysis is taken before the alloy additions, therefore, the values are slightly higher than in the castings. The carbon is controlled as in regular acid melting by manipulation of bed height, type of coke, charge materials, blast temperature, etc.

Figure 9 is a frequency chart of the base silicon and final silicon. It may be noted that 72.5 per cent of the values are within the range of 1.00 to 1.20 per cent

Fig. 5 (left) — Pouring of the test bars used in these tests.

Fig. 6 (right) — The bars were placed on 8 in. centers and a transverse load was applied midway between the centers.

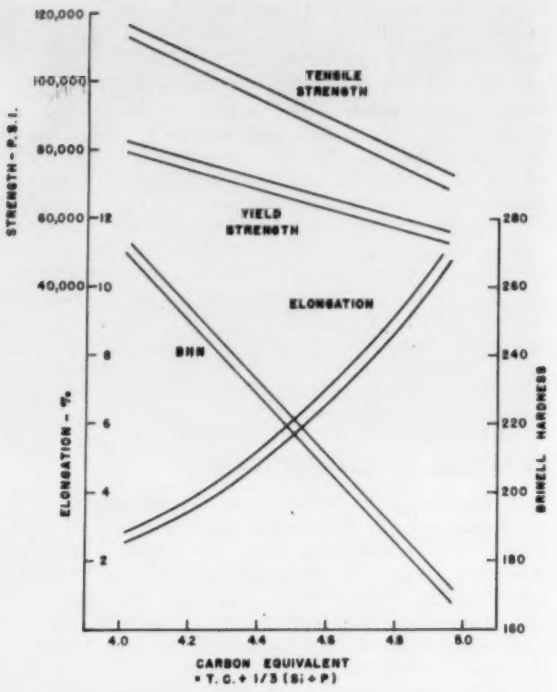

Fig. 7 — Variation in physical properties with carbon equivalent.

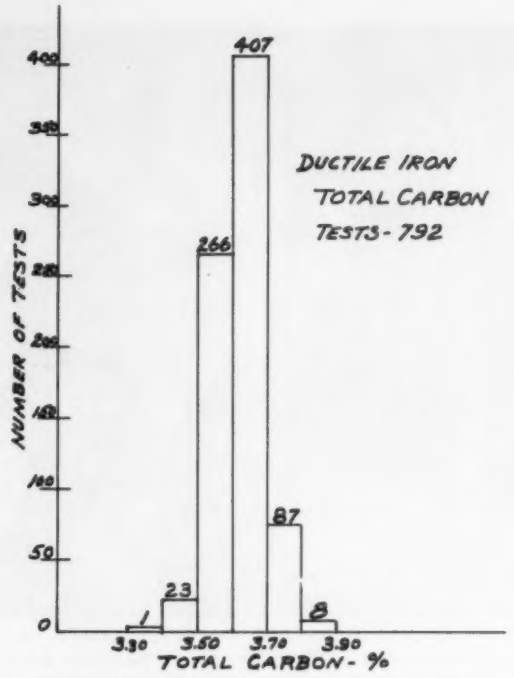

Fig. 8 — Frequency chart for total carbon content.

silicon, and 94 per cent are in the range of 0.90 to 1.30 per cent silicon. The final silicon values are 90.5 per cent within 2.20 to 2.60 per cent and 99 per cent within 2.10 to 2.70 per cent silicon. The base silicon is controlled by the charge materials and operation of the cupola, and the final silicon is controlled by varying the late ferrosilicon addition as indicated by a chill test specimen taken on the base iron.

Figure 10 is a frequency chart of manganese, phosphorus, base nickel and final nickel. The manganese is in the general range of 0.25 to 0.35 per cent, the phosphorus 0.04 to 0.07 per cent, the base nickel 0.30 to 0.50 per cent and the final nickel 0.65 to 0.8 per cent. The second peak in the final nickel chart at 0.85 to 0.90 per cent nickel is due to the difference in alloying procedure between the shell mold foundry and the green sand foundry. More nickel magnesium alloy is added to the ductile iron poured in the green sand foundry due to the size of the castings, the geometry of the ladles and the longer pour-off time.

Stabilizing Elements

Figure 11 is a frequency chart of the carbide stabilizing elements in the metal. These materials should be kept as low as possible in the charge materials in making as-cast ductile iron. The chromium content is generally 0.06 to 0.12 per cent, the copper 0.12 to 0.18 per cent and the molybdenum less than 0.02 per cent.

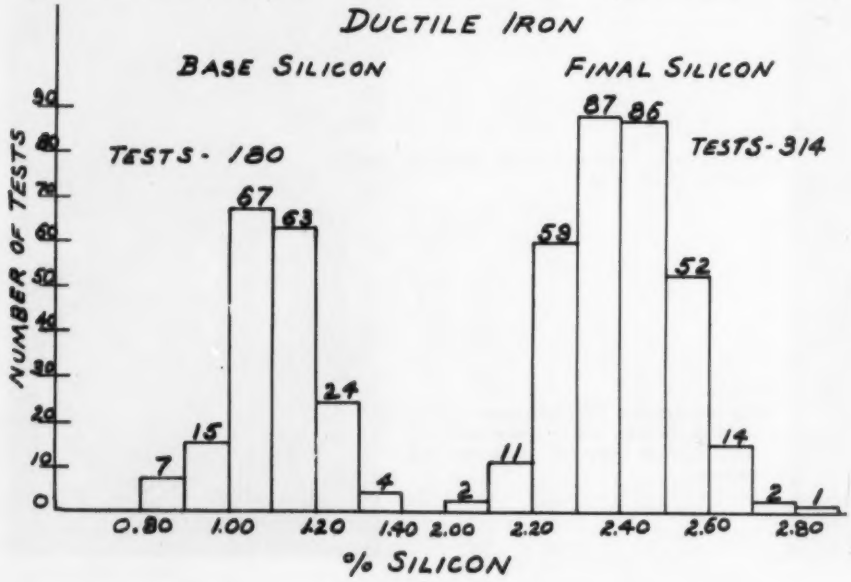

Fig. 9 — Frequency chart of the base silicon and final silicon.

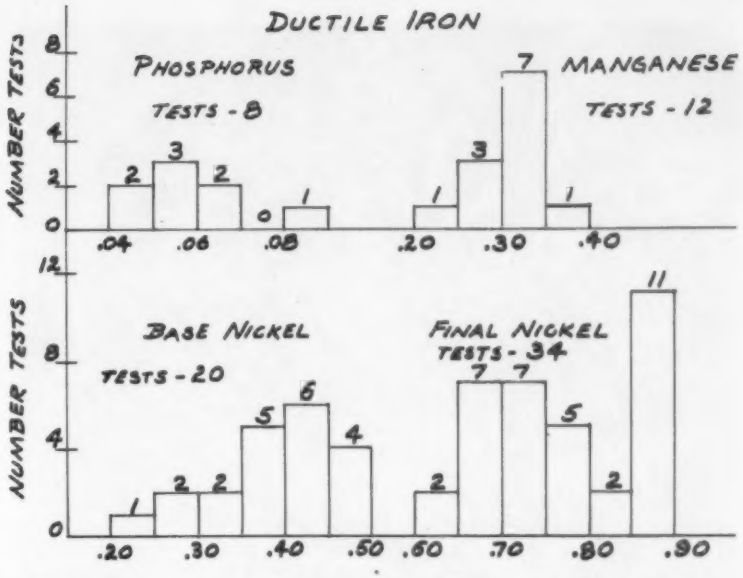

Fig. 10 — Frequency chart of manganese, phosphorus, base nickel and final nickel.

Figure 12 is a frequency chart of the sulfur as tapped from the cupola, and the sulfur after desulfurizing with calcium carbide. No significance is placed on the final sulfur analysis of the treated ductile iron, and therefore the company does not analyze for it. It may be seen that 91 per cent of the cupola sulfurs are in the range of 0.07 to 0.10 per cent; 86 per cent of the sulfurs after calcium carbide treatment are 0.010 to 0.016 per cent and 98 per cent are within the range 0.008 to 0.018 per cent sulfur.

The cupola sulfur is controlled by selection of charge materials, operation of the cupola and selection of coke, whereas the sulfur after desulfurization is controlled by the amount of calcium carbide injected and the operation of the injection technique.

It is felt that the greatest single factor in the successful casting of as-cast ductile iron is maintaining the correct relationship between sulfur, magnesium and cerium in the iron. Since no satisfactory fast analysis for the determination of magnesium and cerium has been found, the control is based on a fast accurate analysis of sulfur and an exact addition of magnesium and cerium based on this analysis.

Figure 13 is a photomicrograph showing carbides in the matrix which cause trouble in machining and tend to reduce the elongation and impact properties. This may be caused by the magnesium content being too high for the section size of the casting, or the carbon equivalent too low.

Figure 14 is a photomicrograph showing wormy graphite in the structure. This causes low physical properties; for example, 65,000 psi tensile, 55,000 psi yield and 4 per cent elongation. It may be caused by low magnesium content or high sulfur content.

Summary

As a summary of the control of composition possible in the preceding procedure of acid melting Table 2 shows the desired analysis and range of the base and final analysis for as-cast ductile iron. The desired total carbon is 3.60 per cent and range ±0.15 per cent. Base silicon 1.10 per cent ±0.15 per cent, the final silicon 2.40 per cent ±0.20 per cent. This gives a carbon equivalent of 4.20 to 4.64, which is an acceptable range for good as-cast ductile iron.

The cupola sulfur is 0.085 per cent ±0.015 per cent, the sulfur after carbide desulfurization is 0.013 per cent ±0.005 per cent, the manganese is 0.30 per cent ±0.05 per cent, the phosphorus is 0.10 per cent (the company's range is 0.04 to 0.08 per cent), the base nickel is 0.40 per cent ±0.10 per cent, the final nickel for the shell foundry is 0.70 per cent ±0.10 per cent, and for green sand 0.85 per cent ±0.10 per cent, the carbide stabilizing elements are

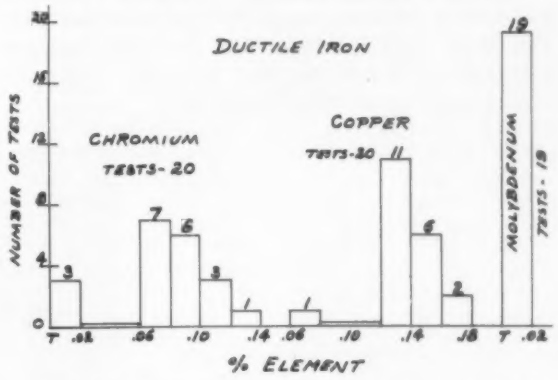

Fig. 11 — Frequency chart of the carbide stabilizing element in the metal.

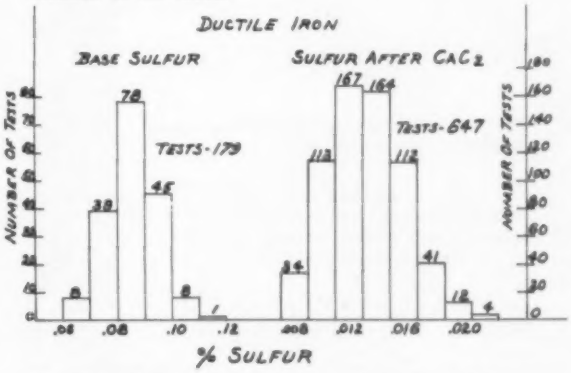

Fig. 12 — Frequency chart of the sulfur as tapped from the cupola, and the sulfur after desulfurizing with calcium carbide.

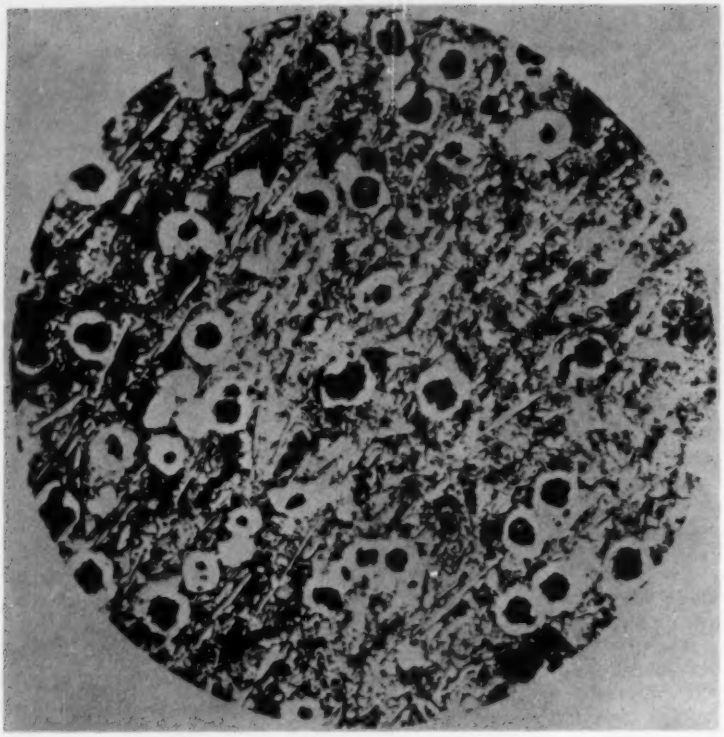

Fig. 13 — Photomicrograph showing carbides in the matrix which cause machining troubles, and tend to reduce elongation and impact properties.

chrome 0.14 per cent max. (the company's range is 0.04 to 0.12 per cent), copper 0.18 per cent max. (the company's range is 0.10 to 0.18 per cent), and the molybdenum is 0.02 per cent max. (the company's range is from a trace to 0.02 per cent).

AS-CAST DUCTILE IRON PHYSICAL PROPERTIES

Figure 15 is a frequency chart of tensile strength and yield point for as-cast ductile iron as measured in a 1 in. keel block. It may be noted that 84 per cent of

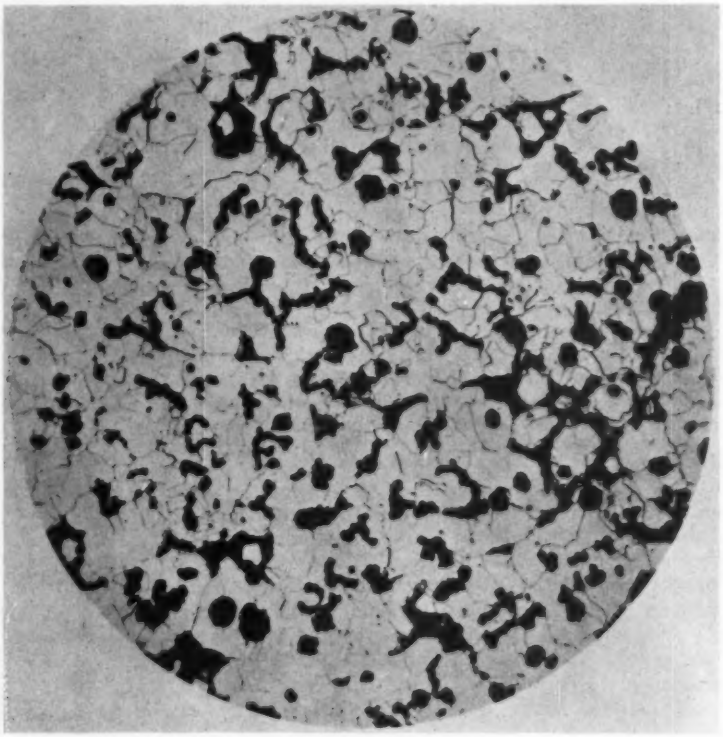

Fig. 14 — Photomicrograph showing wormy graphite in the structure.

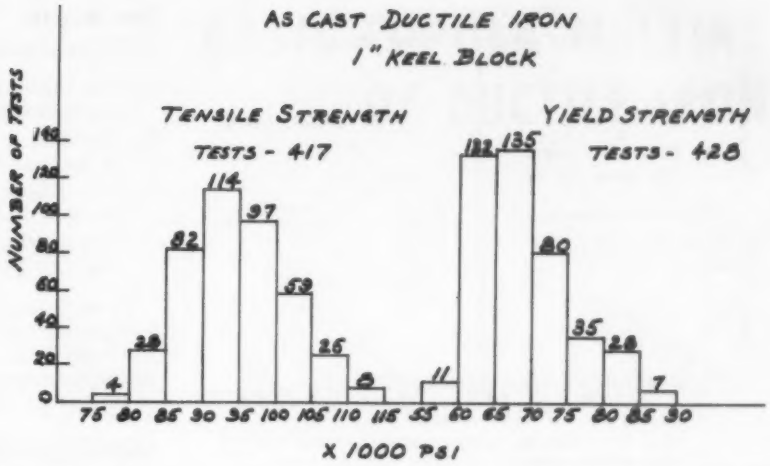

Fig. 15 — Frequency chart of tensile strength and yield point for as-cast ductile iron as measured in a 1 in. keel block.

the values for tensile strength are in the range of 85,000 to 105,000 psi, 96.5 per cent are from 80,000 to 110,000 psi, while 0.95 per cent are under 80,000 psi tensile and, therefore, represent metallurgical scrap. The yield strength values show 89 per cent between 60,000 and 80,000 psi while the values under 60,000 are 2.3 per cent.

Figure 16 is a frequency chart of elongation and Brinell hardness for as-cast ductile iron as measured in a 1 in. keel block. This shows the values of elongation to be 91.5 per cent in the range of 5 to 11 per cent with no values under 3 per cent. The Brinell hardness values are 76 per cent in the range of 200 to 230, and 98 per cent in the range of 180 to 250 Bhn. The tests on the last two frequency charts represent the most questionable ladles of ductile iron, as determined by the transverse test on each ladle.

In addition to the as-cast grade of ductile; i.e., 80-60-03, this iron may be heat treated to grades 60-45-15, 100-70-03 and 120-90-02 or oil quench hardened to Rockwell C hardness of 54 to 58. Also grade 100-70-03 may be made as-cast by raising the manganese to 0.80 to 0.90 per cent and increasing the magnesium alloy slightly.

LATEST TESTS IN BASIC CUPOLA MELTING

It was decided to investigate this field again, incorporating all the knowledge obtained from literature and personal contacts in the industry. These tests were run in the 87 in. I.D. water-cooled cupolas Dec. 15, 1958 and Jan. 8, 1959.

The metal charge consisted of about 60 per cent steel scrap, 30 per cent ductile iron return and cast scrap and 10 per cent low manganese silvery pig iron. The coke charge in Test No. 1 was—15 per cent of a low carbon pickup coke, and in test No. 2—13 per cent of the same coke. The flux charge was 10 per cent dolomite and 2 per cent fluorspar. The air rate

TABLE 2 — RANGE OF COMPOSITION — AS CAST DUCTILE IRON

Element	Desired, %	Range, ± %
Carbon	3.60	0.15
Base silicon	1.10	0.15
Final silicon	2.40	0.20
Base sulfur	0.085	0.015
After CaC_2 sulfur	0.013	0.005
Manganese	0.30	0.05
Phosphorus	0.10 max.	0.02
Base nickel	0.40	0.10
Final nickel	0.70-0.85	0.10
Chromium	0.14 max.	0.04
Copper	0.18 max.	0.04
Molybdenum	0.02 max.	0.01

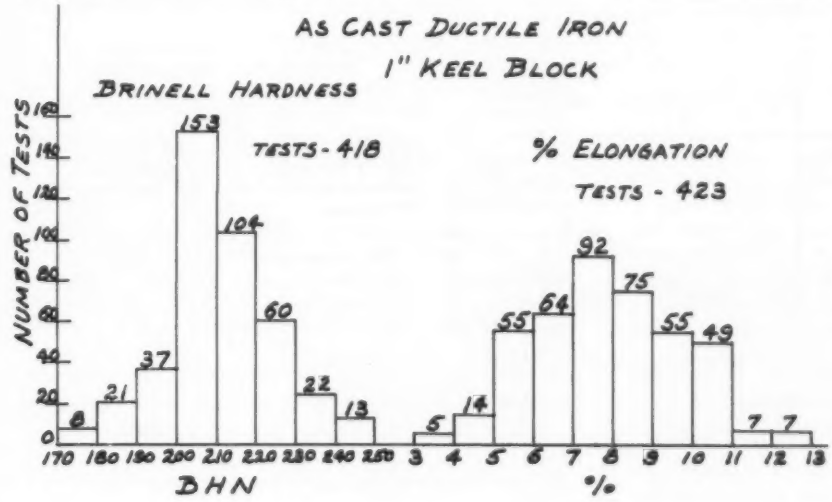

Fig. 16 — Frequency chart of elongation and Brinell hardness for as-cast ductile iron as measured in a 1 in. keel block.

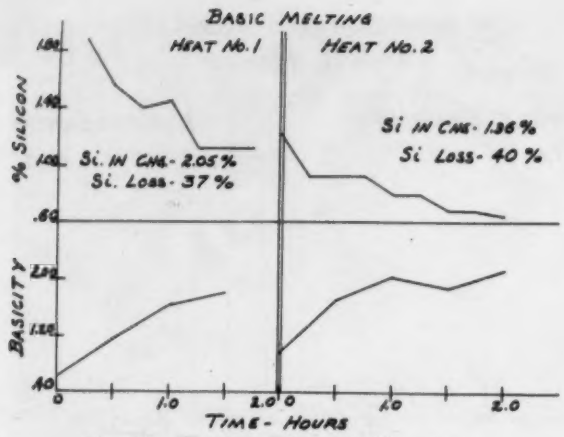

Fig. 17 — Basicity of slag and silicon content of the metal.

was 900 lb/min, and the blast temperature was varied from 600 to 800 F.

Figure 17 shows the basicity of the slag and the silicon content of the metal. It may be noted that as the basicity increases the silicon content decreases. Test No. 1 gave a silicon loss of 37 per cent, and Test No. 2 gave a silicon loss of 40 per cent.

Figure 18 shows the total carbon, and sulfur contents of the metal, the tap temperature of the metal and the MnO and FeO contents of the slag. It may be seen in Test No. 1 that as the tap temperature increases to the maximum of 2940 F the total carbon content reaches its maximum of 3.98 per cent, and the MnO and FeO contents are at a minimum; 0.56 and 0.66 per cent, respectively. Under these conditions the sulfur is reduced to a minimum of 0.037 per cent. Test No. 2 shows that if the tap temperature is maintained at 2800 to 2850 F in order to maintain a maximum carbon content of 3.80, then the sulfur content is in the range of 0.057 to 0.067 per cent.

Test Results

The results of these tests indicate that

1) The sulfur is not reduced to the desired level of less than 0.02 per cent.
2) The total carbon content is above the desired level of less than 3.75 per cent.
3) The silicon loss is about 40 per cent of the charged silicon.
4) The melting rates are only ¾ those of acid melting; i.e., 22½ tons/hr vs. 30 tons/hr.

From these tests it has been concluded that we cannot get the control necessary for making as-cast ductile iron with basic cupola melting, and have, of course, continued to melt acid in the cupolas at both of the author's company's plants.

CONCLUSIONS

Over 4000 tons of ductile iron were poured last year at one of the company's plants, mostly into shell mold castings. Approximately 80 per cent of this production was shipped and used in the as-cast state. The metallurgical, foundry and field losses have been comparable to alloy gray iron castings. All of this iron was melted in the acid cupolas and controlled as given in this report. In addition, six times this amount of gray iron was melted in these same cupolas.

FUTURE WORK

There are, of course, other satisfactory methods of making ductile iron, and there will be new methods and procedures developed. The pressure ladle technique of adding magnesium has been investigated, and the company feels it may have an application on large castings. The plunging technique of adding magnesium is highly thought of, and the company is testing it at the present time. Also the company is continuously working to improve the efficiency of the desulfurizing procedure.

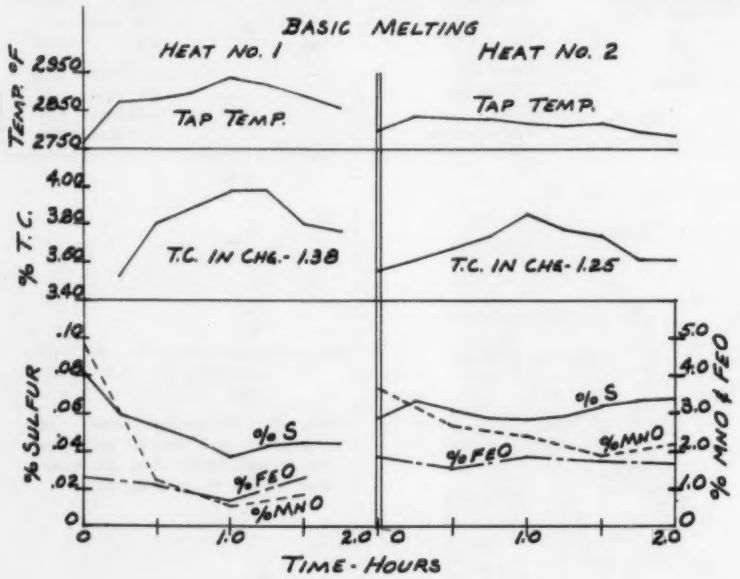

Fig. 18 — Total carbon and sulfur contents of the metal, the tap temperature of the metal and the MnO and FeO contents of the slag.

BASIC CUPOLA MELTING OF DUCTILE IRON

By J. T. Williams

ABSTRACT

The basic cupola melting practice at the author's company is presented, giving the various aspects — slagging technique, metal charge used, basicity required, slag analysis — and other phases.

The advantages and disadvantages of the basic cupola method of melting ductile iron are given, as compared with the acid cupola used at the author's company.

INTRODUCTION

A basic cupola is a variation of the more commonly used acid cupola. It has a basic lining in the melting zone and well, and the charge contains enough lime and magnesia to maintain a basic slag while melting. Basic cupola melting produces a high carbon, low silicon, low sulfur gray iron that has in recent years been used widely in the production of ductile iron and irons subject to thermal shock.

At the author's company a basic cupola for melting ductile iron has been in use since the summer of 1951. The International Nickel Co. has reported that half of the ductile iron produced during 1957 was melted in the basic cupola. The author's company now operates a continuous tap, 78 in. diameter, basic-lined, conventional cupola with a detachable wind box and eight 5 x 7 in. tuyeres.

The cupola is lined with firebrick against the shell followed by magnesite brick in the well and melting zone and a pneumatically placed, stabilized, magnesia enriched, calcined dolomite lining. The melting zone is lined to 48 in.

SLAGGING TECHNIQUE

The front slagging technique of taking metal and slag from the cupola is utilized. Generally speaking the front slagging spout is lined with firebrick, which in turn is covered with carbon brick and a monolithic dolomite lining. This spout regularly gives over 5 hr service. Experience has indicated that a cone bottom bucket, monorail charging system with equipment for accurately weighing each item of every charge provides good control of the ingoing material.

The high carbon, low silicon, low sulfur iron that is tapped from the basic cupola runs over the spout at about 2850 F into a conventional forehearth ladle. From this it is poured into a 500 lb ladle that contains the cerium bearing, magnesium ferrosilicon alloy that is used for making ductile iron. After the alloying reaction is complete, the iron is distributed to the foundry.

J. T. WILLIAMS is Plant Mgr., Reedsburg Div., Grede Foundries, Inc.

The charge that used in the basic cupola operation averages as follows:

Metal Charge	
Purchased steel scrap, lb	900
Gates and sprues, lb	700
50% Ferrosilicon, lb	42
Total metal charge lb,	1642
Flux Charge	
Limestone, lb	115
Fluorspar, lb	22
Total flux charge, lb	137
Coke Charge, lb	215
Coke Ratio	7.6 to 1

The typical gray iron chemistry resulting from this charge is:

Carbon, %	3.90
Silicon, %	1.40
Manganese, %	0.45
Sulfur, %	0.025
Phosphorus, %	0.025

This chemistry allows the addition of a minimum of alloy to produce ductile iron, thus reducing ladle slag, alloy costs and temperature losses to a minimum.

SCRAP STEEL USE

One of the advantages of operating a basic cupola is that scrap steel, which is considerably less expensive than pig iron, is the only raw material used in the metal charge. The use of such a large amount of scrap steel is possible because the basic slag continually fluxes the ash from the coke and makes a relatively large amount of carbon available for combination with the metal. Carbon pickup in the basic cupola is about 2-2.25 per cent.

Another advantage of this method of melting is that the use of this large amount of low phosphorus steel scrap results in a low phosphorus iron. Several investigations, including work at the Naval Research Laboratory, have shown that the lower the phosphorus content the lower will be the ductile brittle transition temperature of ductile iron. For the same reason it is desirable to keep the final ductile iron silicon content below 2.5 per cent.

A disadvantage of basic melting is also apparent. Where usually less than 10 per cent of the silicon is lost in acid melting, the basic cupola losses are 35-40 per cent. Not only does this make necessary the use of more ferrosilicon, but it also produces more silica (SiO_2), which reduces the basicity of the slag. Use of a hot blast will reduce the silicon loss during melting. Because of this, less silica (SiO_2) is formed to reduce the slag basicity.

BASICITY REQUIRED

A larger percentage of flux is used than in acid melting to achieve the degree of basicity required to produce the type of iron that it is felt meets the company's requirements for making ductile iron. Thus, acid practice fluxing costs are about one-fifth basic fluxing costs. This large quantity of slag becomes too viscous to remove from the cupola, and a secondary flux is needed to give the molten slag fluidity. A 1 x 4 in. lump Mexican grade of fluorspar containing 97 per cent effective calcium floride (CaF_2) has been successfully used for this purpose.

While there are several ways of calculating slag basicity, the following method will be used at this time:

$$\text{Slag basicity ratio} = \frac{CaO + MgO}{SiO_2 + Al_2O_3}$$

Acid cupolas generally operate with slags having a basicity ratio of 0.3 to 0.5. Basic cupolas operate with slags having a basicity ratio over 1.3. Slags with ratios between these limits are generally considered to be neutral. On the average the flux charge results in the following slag analysis:

Lime (CaO), %	52
Magnesia (MgO), %	18
Silica (SiO_2), %	24
Alumina (Al_2O_3), %	3

This slag has a basicity ratio of 2.6 which is considered very basic. I have not mentioned the contribution that lining consumption makes to the above basicity ratio, but it is substantial.

DUCTILE IRON PRODUCTION

Acid cupola sulfurs run 4-5 times higher than the author's company's basic cupola sulfurs. This makes basic melting advantageous to ductile iron production, because the nodularizing alloy added to the base iron must first counteract the effect of certain undesirable elements. Sulfur is the most likely of these to be present. After the undesirable elements have been counteracted, the unconsumed excess of magnesium is available to spherodize the graphite.

Investigations have shown that sulfur reduction takes place when the sulfur in the iron reacts with lime (CaO) and magnesia (MgO) in the slag. The calcium sulfide (CaS) and magnesium sulfide (MgS) formed leave the cupola in the slag. Magnesia (MgO) is less effective in combining with sulfur than lime (CaO); and therefore, a ¾ x 2 in. lump, high calcium limestone is used rather than a dolomitic stone.

The desulfurizing power of the slag is reduced if oxidizing conditions exist and high quantities of iron oxide (FeO) are present, because the chemical reaction tends to reverse itself and return the sulfur to the iron.

Consumption of the dolomitic lining is high, and additional flux is added to the slag as the lining erodes. Comparisons with the acid cupola operations show that the basic cupola consumes at least 50 per cent more lining than does the acid cupola. Considering that acid lining costs about $14.50 per ton, and basic lining costs about $58.00 per ton, the basic patch material cost alone is at least six times the acid patch material. In addition, magnesite brick is more expensive and shows a shorter life than acid firebrick.

WATER-COOLED CUPOLAS

As metal requirements increase and the melting period becomes longer, water-cooled cupolas, usually in conjunction with hot blast, are used. In this case a minimum amount of refractory and lining are used, thus, in part, overcoming the higher basic lining cost.

Research and experimental data now available establish the following basic cupola melting principles:

1) The higher the slag basicity, the greater the carbon pickup.
2) The higher the slag basicity, the lower the final sulfur content.
3) For a given basicity, the higher the temperature, the higher will be the carbon pickup and the lower the sulfur.
4) The higher the slag basicity the greater the silicon loss.
5) There is no change in phosphorus content of the iron during melting.

The basic cupola is a melting unit in which the degree of complexity increases as the basicity of the slag increases. In order to operate a cupola of this type properly, it is imperative that all charge materials be of first quality and that they be weighed accurately. It is also important that the incoming air be controlled closely, that tap temperatures be constant and that chill tests be taken frequently so that adjustments can be made for variations.

ADVANTAGES AND DISADVANTAGES

Reasonably uniform ingoing returns, clean scrap and a skillfully lined cupola for uniform lining consumption will help to insure fairly consistent chemistry. The erosion of a large piece of lining can drastically change slag basicity and will have an unfavorable effect on the operation.

Some of the advantages of basic cupola melting are:

1) Low sulfur iron can be tapped from the cupola.
2) High carbon pickup allows the use of lower cost, low phosphorus steel scrap in the charge.
3) More suitable base iron is available for ductile iron production.
4) Somewhat higher tapping temperature.
5) Good slag fluidity.

Some of the disadvantages of basic cupola melting are:

1) Higher daily patching cost.
2) Higher lining costs.
3) Higher silicon loss during melting.
4) Greater volume of slag to handle with accompanying higher material cost.
5) More skills and more exact control are needed to operate successfully.
6) Higher fluxing cost.

CONCLUSIONS

It can be said that the basic cupola at the author's company has given all who have come in contact with it more mental exercise than any other melting unit in the company has in a good long time. To operate a basic cupola requires a degree of skill and attention far above that required to operate an acid cupola, because the acid cupola seems to adjust itself to a given set of operating conditions. This degree of skill and attention applies to every aspect of the melting operation.

RAMMING, SUPERHEAT AND ALLOYS (TYPE OF METAL) EFFECTS ON METAL PENETRATION

Report of Sand Division, Mold Surface Committee 8-H

Prepared by G. J. Vingas

ABSTRACT

Metal penetration, as discussed here, is that penetration into small masses of sand surrounded by relatively large masses of metal. The major and minor variables which influence this penetration are given. This report is a continuation of work done previously with metals other than iron and steel. The metals used for these tests are aluminum, brass, gray iron, steel and Wood's metal.

INTRODUCTION

Previous reports of the Mold Surface Committee, or those of its chairmen and members, have thoroughly covered the subject of penetration of steel and iron into small masses of sand. These reports extend back in the AFS TRANSACTIONS for a period of over ten years. The following variables have been found to influence penetration into small masses of sand surrounded by relatively large masses of sand and iron:

Major Variables

1) Relationship of mass of sand to mass of metal.
2) Pressure, as determined by the height of liquid metal above the sand surface into which the metal is penetrating.
3) Void size of the sand mass. In all but rare instances this void size is that of the sand as rammed. Under severe conditions, void size to prevent penetration is small, and the controlling factor becomes density, the amount of voids.

Minor Variables

1) Superheat.
2) Metal flow.
3) Washes and coatings, expect when the major variables are not severe.
4) Glazing (sintering).
5) Gas pressure (very minor).
6) Veining (a contributary cause).

All the above variables are interrelated, therefore, a simple analysis based on one variable is usually impossible. It should be emphasized that it has always been possible to explain penetration by one, or more of the preceding factors. In no case have oxides, compounds of any type, volatilization or sublimation been found to cause or effect penetration. The action is mechanical.

All chemical changes in the penetrated metal are those expected, due to oxidation and decarburization of ferrous metals when in contact with air and mold gasses. As will be shown in this report, chemical changes in copper-base alloys are due to normal selective freezing during solidification.

This report is a continuation of previous work with metals other than iron and steel. A statistically controlled, quantitative evaluation has been made of the following variables:

Absolute Temperature, as determined by the metal, aluminum, brass, gray iron, steel and Wood's metal.

Relative Temperature, as determined by three levels of superheat for each metal.

Void Size, a relatively small change in void size as determined by four levels of ramming of the same mold.

Test cores were made of a blended sand with the properties listed in Appendix 1. The cores contacted the metal under severe conditions of mass and pressure in a modified Gertsman test casting, as in Fig. 1. The degrees of penetration were evaluated by the members of the committee in degrees of severity from 0 to 9 (Fig. 2) according to the method outlined in the previous committee report. The individual evaluations were analyzed statistically, as detailed in Appendix 2.

The five metals were poured at constant levels of superheat, measured in Btu/cu in. above each liquidus level. In this way superheat can be separated

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Mold Surface Committee (8-H) consisted of the following personnel: G. J. Vingas, *Chairman;* J. E. Haller, *Vice Chairman;* J. G. House, *Secretary;* J. B. Caine; R. Dietert; R. Gregory; C. E. McQuiston; A. E. Murton; J. A. Ridderhof; R. W. Ruddle; R. R. Schaaf; C. J. Schwetz; C. C. Sigerfoos; and D. C. Williams.

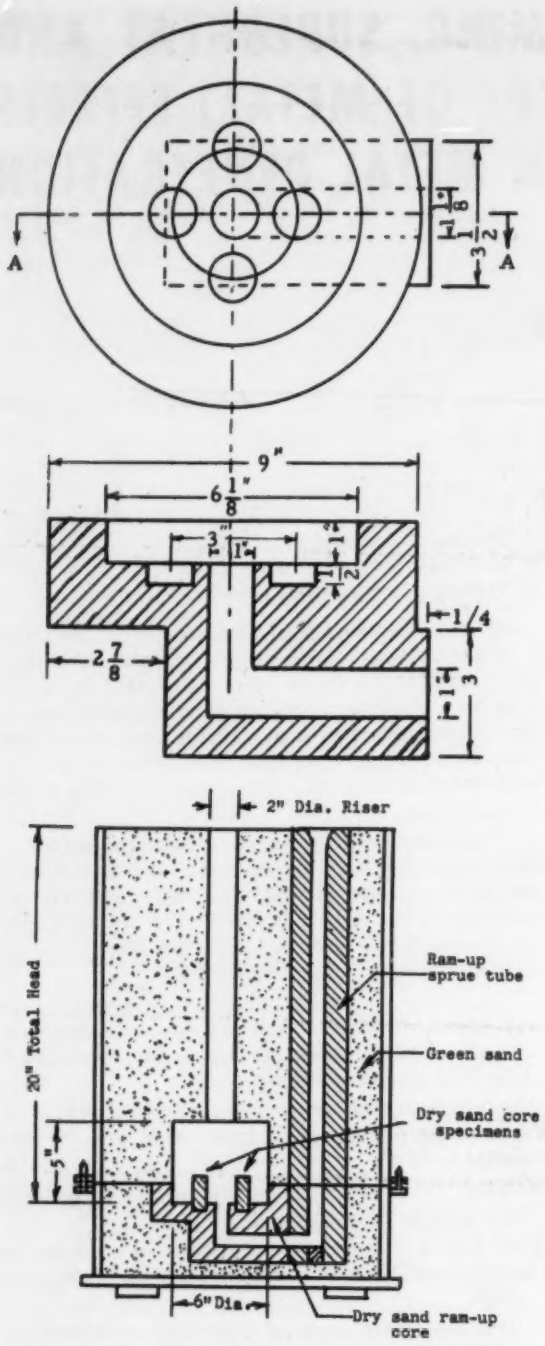

Fig. 1 — Dry sand ram-up cores (top) and modified Gertsman test mold (bottom).

from absolute temperature as determined by the liquidus level of each metal. The degrees of penetration for the five metals are shown in Table 1.

The following general conclusions can be drawn:

1) The type of metal must be added to the list given previously as a major variable.
2) Temperature per se has no influence on penetration. This point is accented by the Wood's metal experiments. These experiments were designed with just this point in mind. By far the worst penetration was experienced with this metal poured at a temperature below boiling water.

CONCLUSIONS

A statistical analysis of the minor variables leads to the following conclusions:

1) The experimental error is low. Within the limits of the experiment, the causes of penetration have been found.
2) For aluminum, ramming affects penetration while superheat does not.
3) In the case of brass, ramming does not affect penetration while superheat is an exceedingly important variable.
   For iron, both ramming and superheat have an effect.
4) The sands of Table 1 were penetrated in both steel and Wood's metal regardless of the pouring temperature differential and pressure head.

Pressure for a given metal was constant. Differences in pressure due to the densities of the various metals is one factor causing the great difference in penetration of the five metals.

The penetrated metal, of the brass and Wood's metal castings, was checked for changes in chemical composition.

Brass			Wood's Metal		
	Casting, %	Penetration, %		Casting, %	Penetration, %
Cu	84.6	69.8	Bi	48.0	49.4
Pb	4.6	14.6	Pb	22.8	20.3
Sn	4.8	11.3	Sn	13.1	17.4
Zn	5.5	3.2	Cd	16.7	13.0
P	0.029	0.032			

It will be noted that in the case of the brass casting the percentages of the lower melting constituents, except zinc, are higher in the penetrated metal. This situation should be expected from selective freezing. Volatilization of zinc is an added variable. Wood's metal is close to a quatenary eutectic, and no great change in chemical composition should be expected.

It should be emphasized that penetration, as dis-

TABLE 1 — PENETRATION OF TEST CASTING (AVG. OF SEVEN EVALUATIONS)

No. of rams	Density, % solid	Superheat Levels												Steel	Wood's Metal
		Aluminum			Brass			Iron							
0	54.5	0.71	0.86	1.0	6.8	8.3	8.8	1.0	1.4	1.8	over 9 for	completely
1/4	57.2	0.43	0.43	0.43	6.4	8.3	8.8	1.0	1.3	1.4	all degrees	penetrated
1	59.0	0.14	0.14	0.0	6.4	8.0	9.0	0.28	0.71	0.71	of ramming	under all
3	60.7	0.0	0.0	0.0	6.3	8.0	8.8	0.0	0.28	0.43	and super-heat	conditions

cussed in this report, is that into small masses of sand surrounded by relatively large masses of metal. Such penetration may differ from slight penetration that causes variation in surface smoothness when the relative masses of sand and metal are reversed. This latter case is now the concern of the Committee.

APPENDIX 1

Cores were made of the following sand mix:

Sand	Per Cent
Port Crescent	38
Juniata Bank	47
Silica Flour	5
Cereal	1.25
Core Oil	1.75
Iron Oxide	1.50

Mulled	Time, min
Dry Additions	1
Water	2
Core Oil	3
Total	6

Baked at 400 F, 1½ hr
Distilled water, pH 6.2, added to 4.9 per cent

Screen analysis of the sand

Screen Size	Retained, %
43	trace
53	trace
60	12.1
70	37.0
100	27.2
140	11.8
200	6.1
270	2.8
Pan	3.0
AFS fineness no.	77

The physical properties of the sand

Green permeability	56
Green strength, psi	1.5
Green hardness	63
Flowability (Dietert)	84
Deformation, in./in.	0.050
Baked compressive strength, psi	789
Baked tensile strength, psi	166
Baked scratch hardness	90-95
Overhang, no. jolts, low cam	27
Overhang, no. jolts, high cam	9
Cracking, no. jolts, low cam	175
Cracking, no. jolts, high cam	67
Sagging, at 5 jolts, in.	0.0095

No spalling at 2 or 12 min at 2500 F; a few hairline cracks.

	0 Ram	¼ Ram	1 Ram	3 Rams
Free expansion, 1500 F, in.	0.030	0.029	0.026	0.027
Baked density, % solid	54.5	57.2	59.0	60.7

APPENDIX 2

To calculate the degree of superheat, the following equation was used:

$$Q = WC\,(t_2 - t_1)$$

where:

Q = heat addition in Btu.
W = lb of metal.
C = ave. specific heat.
t_1 = melting point.
t_2 = temp. attained after heat addition.

It was decided to add Btu/in.² of molten metal as follows:

Btu/in.² added	Gray Iron	Copper	Aluminum	Wood's Metal	Steel
300	2395	1935	1285	360	2785
600	2490	2020	1415	560	2850
900	2550	2110	1545	770	2910

When Wood's metal was cast it could not be contained in regular fine sand, therefore, it was decided to calculate the superheat on a ratio of pouring temperature relative to the other metals, as:

TEMPERATURE OF SUPERHEAT

	Metal Temperature			
Btu/in.² added	Gray Iron	Copper	Aluminum	Steel
300	1.015	1.045	1.707	1.022
600	1.07	1.102	1.220	1.045
900	1.09	1.140	1.330	1.062

Wood's metal was then calculated, based on the ratio of aluminum; 1.1, 1.2 and 1.3, and was poured at 174, 189 and 206 F.

CHEMICAL AND THERMAL PROPERTIES OF METALS

	Chemical Composition				
	Gray Iron	Copper Alloy	Aluminum Alloy	Wood's Metal	Steel
	C, 3.0-3.2	Cu, 82.5	Al, 92.21	Pb, 26.0	C, 0.25
	Mn, 0.78	Sn, 4.53	Cu, 4.66	Sn, 13.0	Mn, 0.70
	P, 0.12	Pb, 4.72	Si, 2.40	Cd, 12.0	Si, 0.50
	S, 0.06	Zn, 5.45	Mn, 0.17	Bi, 49.0	
	Si, 1.75		Fe, 0.56		
Specific heat, Btu/lb/F	0.165	0.110	0.230	0.041	0.18
Latent heat of fusion, Btu/lb	41.4	79.9	93.0	17.2	52.5
Melting point, F	2330	1850	1160	158	2725
Density, Lb/in.³	0.26	0.316	0.101	0.36	0.28

APPENDIX 3

STATISTICAL ANALYSIS OF TESTS PERFORMED

A three way analysis of variance, i.e., three independent variables, namely metal, superheat and ramming acting on the dependent variable, metal penetration, was performed. In an analysis of variance, the hypothesis tested is that no independent variable or combination of independent variables influence the dependent variable.

If the amount of variation of the dependent variable caused by an independent variable or combination exceed the chance probability, then the basic hypothesis is rejected and the independent variable is said to be significant. This means that variation caused by the independent variable can not be due to chance, and thus must be a cause and effect relationship.

In this analysis the significance level was chosen as 0.95, i.e., assignable cause of variance could be made with a probability of accuracy 95 times out of 100. $F_{0.95}$ is the F ratio for this 0.95 probability of being correct.

By examination of the above table the following conclusions can be drawn based on the experiment:

1. The experimental error is low; the assignable causes of penetration have been investigated.
2. Two interactions were found to cause penetration; metal-ramming and metal superheat.

When interactions are found to be significant, as above, the independent variables can not be tested

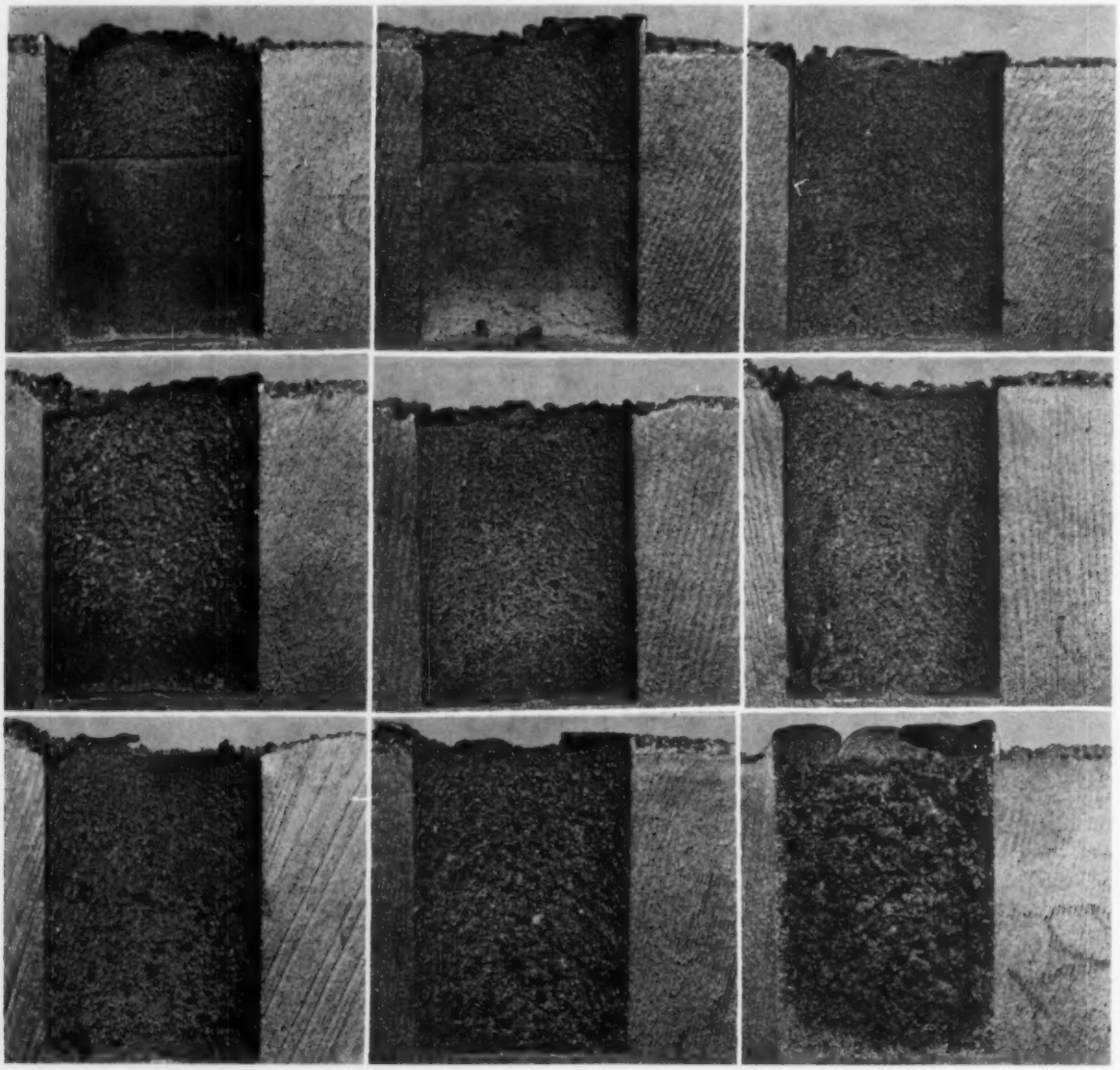

Fig. 2 — Typical results of standard Gertsman tests (re: C.C. Sigerfoos). *Top row* (left to right) — Silica flour, X 300 normal; Silica flour, X 200 normal; Crystalline graphite, X 200 skew right. *Center row* (left to right) — Mexican graphite, X 300 normal; Mexican graphite, X 200 normal; Crystalline graphite, X skew right. *Bottom row* (left to right) — Crystalline graphite, X 300 skew right; Crystalline graphite, X 300 normal; Uncoated, X skew right.

for significance singly. To illustrate, the interaction is analogous to $x \cdot y = a$. It is not possible to plot a knowing only x.

To overcome this problem, a further analysis was performed called a breakdown analysis of variance. Here the level of variables is reduced by one. In this case a breakdown analysis was performed for each metal. The results are given in the table of Analysis of Variance.

It should be remembered that the following conclusions are limited to this experiment, and any generalization to actual practice should take into consideration the limits of this experiment.

The table following is the result of the analysis of variance for this experiment.

Source of variation	Sum of square	d.f.	Mean square	F	$F_{0.05}$	Sign
Metal	419.74	2	109.87			
Superheat	6.04	2	3.02			
Ram	3.19	3	1.06			
Interactions						
Metal superheat	6.41	4	1.60	7.37	3.26	Yes
Superheat, ramming	0.02	6	0.00333	<1.0	3.00	No
Metal-ramming	1.06	6	0.1766	8.14	3.00	Yes
Error	0.26	12	0.0217			
Total	436.72	35				

d.f. = degrees of freedom.

The conclusions that can be drawn for the analyses are:

1) The causes of penetration in this experiment have been found, as the experimental error is low.
2) For aluminum, ramming affects penetration while superheat does not.
3) In the case of brass, the ramming does not affect penetration, while superheat is an exceedingly important variable.
4. For iron, both ramming and superheat have an effect.

ANALYSIS OF VARIANCE

Source of variation	Sum of square	d.f.	Mean square	F	$F_{0.05}$	Sign
M_1 Aluminum						
Ramming	1.42	3	0.473	82.98	4.35	Yes
Superheat	0.01	2	0.005	0.88	4.74	No
Error	0.04	7	0.0057			
Total	1.47	12				
M_2 Brass						
Ramming	0.11	3	0.0366	1.60	4.35	No
Superheat	11.91	2	5.96	260.26	4.74	Yes
Error	0.16	7	0.0229			
Total	12.18	12				
M_3 Iron						
Ramming	2.73	3	0.91	91.0	4.35	Yes
Superheat	0.53	2	0.265	26.5	4.74	Yes
Error	0.07	7	0.01			
Total	3.33	12				

d.f. = degrees of freedom.

COMPARISON OF X-RAY QUALITY AND TENSILE PROPERTIES IN CAST HIGH STRENGTH STEEL

By H. R. Larson, H. W. Lloyd and F. B. Herlihy

ABSTRACT

Results of tests performed with x-rays to correlate soundness with tensile properties are given. Plates ½ and 1 in. thick were used for this investigation. Tensile test bars 0.505 or 0.252 in. in diameter were machined from these plates. Radiographs were taken of ⅛-in. slices ground to 0.020 in. and examined for traces of shrinkage at 20×. Results indicate that slight traces of microshrinkage have a rather pronounced effect on ductility of tensile specimens of cast ultra high strength steel.

INTRODUCTION

The problem of developing high integrity steel castings for aircraft applications is obviously not a simple one. To be competitive with other materials they must be heat treated to high strength levels, 180,000 psi or above. At these high strength levels ductility and impact strength are lower than at the strength levels commonly used today. Because of this increased notch sensitivity, it is quite possible that casting defects will have a more detrimental effect on properties than the same defects at lower tensile strengths.

Although random dirt and slag defects, blowholes, etc., can be minimized by careful foundry practice, microshrinkage may be present to some extent in all except the most carefully fed areas. The effect of varying amounts of microshrinkage on the tensile properties at high strength levels is an unknown factor.

Before investigating the effect of unsoundness, it is necessary to determine the ultimate properties which can be developed in well fed test bars. The authors, in another paper,[1] have described alloy compositions, melting practices and heat treatments which gave improved mechanical properties in test bar castings. Although the ultimate goal is to produce castings in which metal quality approaches these test bar properties, it seemed that a logical intermediate step would be to investigate properties in simple shapes in which unsoundness would be present in varying degrees.

Thus, it would be possible to correlate mechanical properties with x-ray quality. It would also offer a rough guide as to the distance from risers and chills that one could expect adequate mechanical properties.

In an extensive series of investigations[2,3,4] Pellini and coworkers have shown that the distance which plate and bar castings can be fed sound is a function of the thermal gradients set up by the heating effect of risers and the chilling effect of edges, ends and chills. They used x-rays of the various sections to establish the limits of soundness. However, no effort was made to correlate soundness with tensile properties.

PROCEDURE

Casting Practice

The simple shapes chosen for study were plates with thicknesses of ½-in. and 1 in. The 1-in. thick plates were 6½ in. wide and 3¾, 5¾ and 7¾ in. long with a 3 in. x 6½ in. x 6 in. high hot metal riser. The ½-in. thick plates were 6 in. wide by 2, 3, 4 and 6 in. long with a 2 in. x 6 in. x 6 in. high hot metal riser.

These plate castings were poured in both oil bonded dry sand and ceramic molds, and both with and without steel chills at the ends of the plates opposite the risers. The chills were 1½ in. x 2 in. x 9 in. for the 1 in. plates and 1½ in. x 3 in. x 7 in. for the ½-in. plates.

A test bar casting, Fig. 1, was also poured with each heat. This "octabar" casting was designed for use with cast steel and yields eight 1 in. x 1 in. x 6 in. test coupons per casting. Both oil bonded dry sand and ceramic molds were used for these castings.

All castings were poured between 2950 F and 3050 F with the risers immediately covered with an exothermic hot top compound.

After cleaning and removal of the risers, the plates were x-rayed with a sensitivity of two per cent or better. They were then sectioned into alternate tensile blanks and ⅛-in. slices for microradiographs.

The tensile blanks were heat treated as follows: 1850 F–2 hr-A.C., 1575 F–2 hr-oil quench, 400 F–6 hr-A.C. Tensile bars with diameters of 0.505 or 0.252 in. were then machined from the 1 in. and ½-in. plates, respectively. The tensile specimens were shoulder grip rather than threaded specimens. A drawing of the 0.505 in. specimen is shown in Fig. 2.

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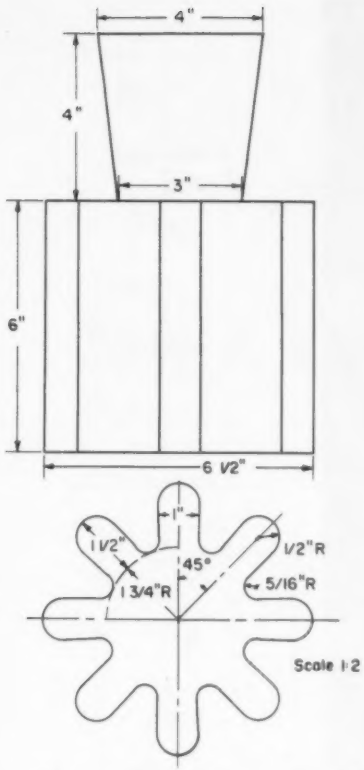


Fig. 1 — Test coupon design for cast steel.

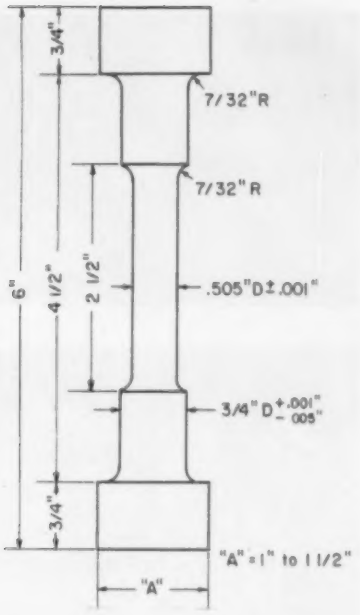


Fig. 2 — Shouldered round tension test specimen.

The 1/8-in. slices were ground to 0.020 in. and radiographed on fine grain film. The radiographs were examined for traces of shrink under a microscope at 20×. Typical x-rays of the 0.020 slices magnified 10× are shown in Fig. 3. Absolutely sound x-rays were rated zero, and those with shrink were rated 1 through 4. The portion of the cross-section of the 1/2-in. plate tested by a 0.252 in. diameter tensile bar has been marked on the photographs.

Melting and Deoxidation Practice

Four heats of 500 lb were made in an induction furnace of 650 lb capacity which was lined with a rammed proprietary composition of $MgO{\cdot}Al_2O_3$. One heat of 220 lb was made in an induction furnace with a magnesia crucible.

These heats were made with high purity charge materials including special sponge iron briquets, ferromolybdenum, electrolytic chromium, nickel, graphite and high purity revert. Sponge iron heads form a considerable amount of slag on melting which was skimmed off before additions. After the bath reached 3000 F to 3050 F, ferrosilicon and electrolytic manganese were added.

All heats were tapped at 3200 F into basic lined ladles. CaMnSi in the amount of 6 lb/ton was added to the bottom of the ladle just prior to the tapping. Aluminum wire (0.06 per cent) was wrapped on a steel rod and plunged at about half tap.

Analysis of heats is shown in Table 1.

Tensile data and microradiographic results for 1/2-in. plates are presented in Figs. 4 and 5, and for 1 in. plates in Figs. 6 and 7. Figures 5 and 7 also present tensile data from 0.505 in. tensile specimens cut from the octabar test castings for comparison.

TABLE 1 — CHEMICAL ANALYSIS OF HEATS

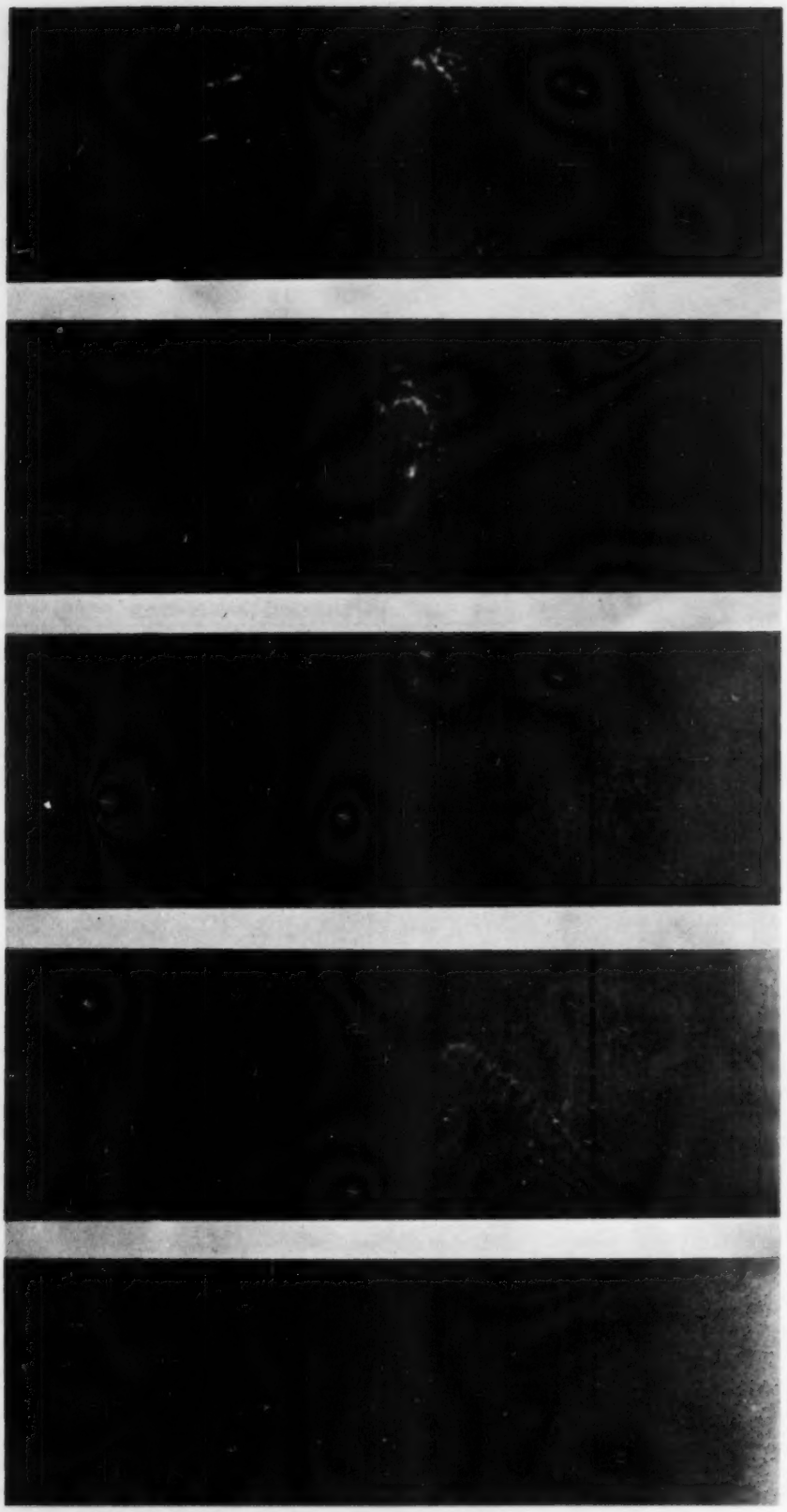
Heat No.	Composition, %								
	C	Mn	P	S	Si	Ni	Cr	Mo	Al
58-327-1	0.39	0.68	0.009	0.013	0.36	0.59	0.85	0.40	0.031
58-333	0.42	0.77	0.015	0.011	0.38	0.60	0.89	0.40	0.046
58-339	0.40	0.67	0.010	0.013	0.30	0.59	0.90	0.40	0.050
58-349	0.36	0.59	0.010	0.013	0.30	0.59	0.82	0.41	0.072
58-368	0.34	0.89	0.010	0.014	0.39	0.59	0.85	0.40	0.044

RESULTS

It is evident that as the length of the plate increases the tendency for shrinkage and inferior properties in the center of the plate increases also. The correlation between microradiographs and ductility is rather good. Unless the test bar contains gross defects there is only a negligible change in yield or tensile strength.

The microradiograph technique applied to the 0.020 in. sections is a much more sensitive method of detecting shrinkage than is the x-ray of the plates as a whole. For example, all x-rays of the 1 in. plates poured in ceramic molds were free of shrinkage. On the other hand microradiographs of thin sections indicated considerable unsoundness in 6 in. long plates and lesser amounts in the other plates. Similarly, in the 1/2-in. plates poured in ceramic only the 6 in. plates had unsoundness by x-ray. The thin slices showed unsoundness in 3 and 4 in. plates as well. Because of surface roughness and dirt, it was difficult to interpret the x-ray of the sand cast plates.

Chilling increases the feeding distance, as would be expected. This can be seen most readily by comparing data for chilled and unchilled 1/2-in. plates with lengths of 4 in. in Fig. 4, and 1 in. plates 6 in. long in Fig. 6. Also, the sections next to the chills exhibit some exceptionally good properties. For example, one



4 — Severe shrink

3 — Considerable shrink

2 — Some shrink

1 — Small shrink

0 — Sound

Fig. 3 — Classification of shrinkage. Radiograph of 0.020 in. slice from a ½-in. thick plate. Dotted lines show extremes of 0.252 in. test bar. 10×.

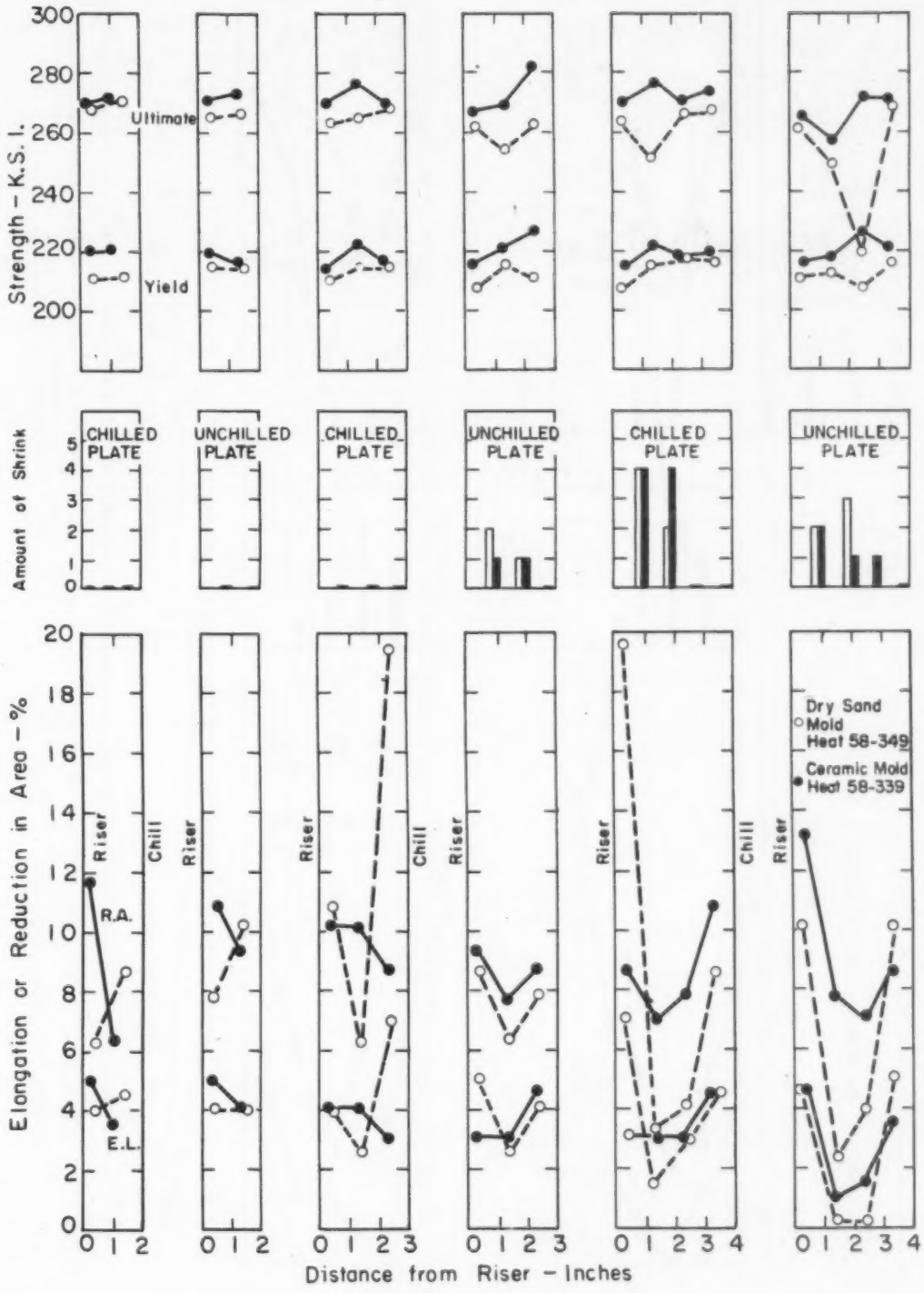


Fig. 4 — Feeding distance in ½-in. plates — 2, 3 and 4 in. long. Test bars are 0.252 in. diameter.

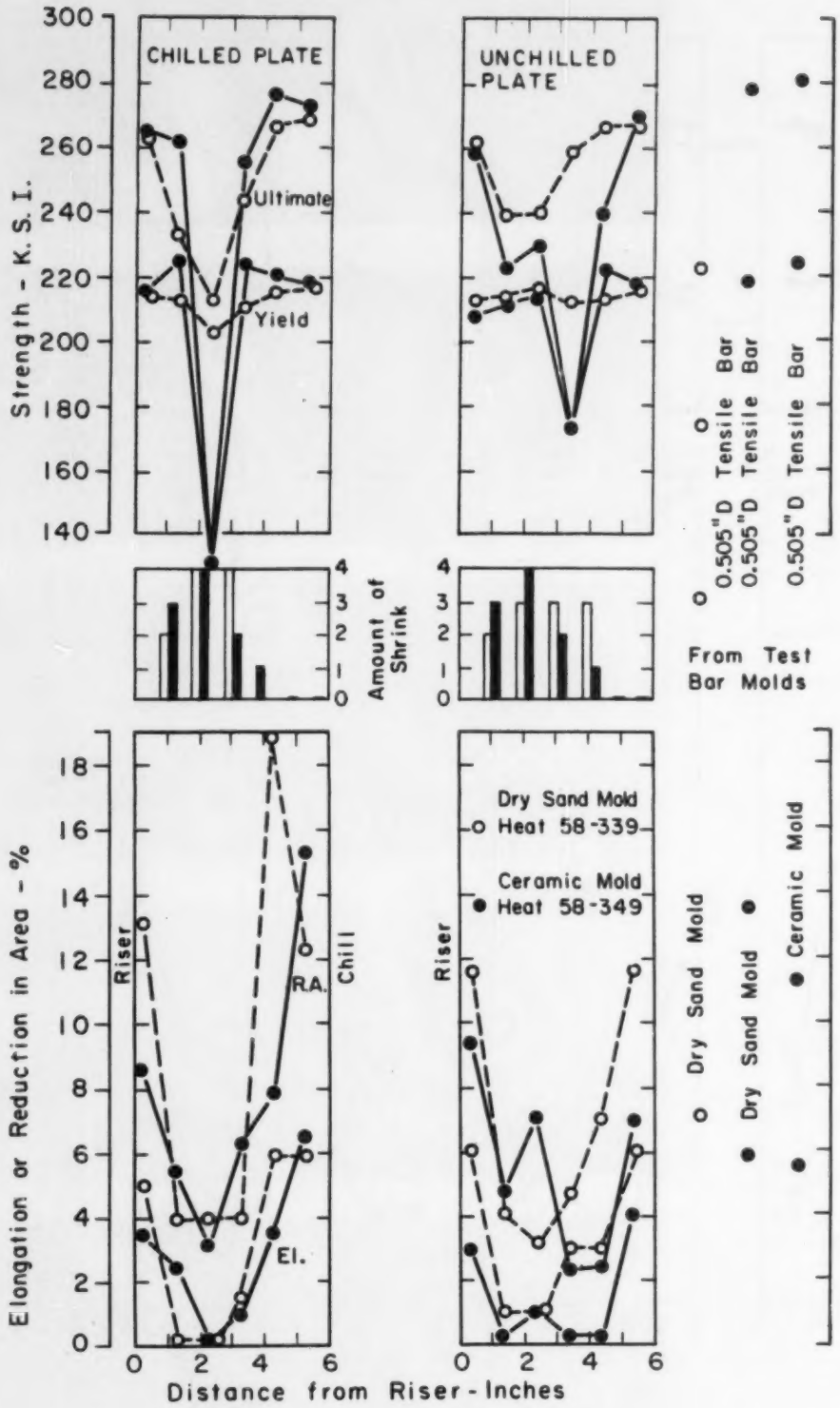


Fig. 5 — Feeding distance in ½-in. plates — 6 in. long. Test bars are 0.252 in. diameter.

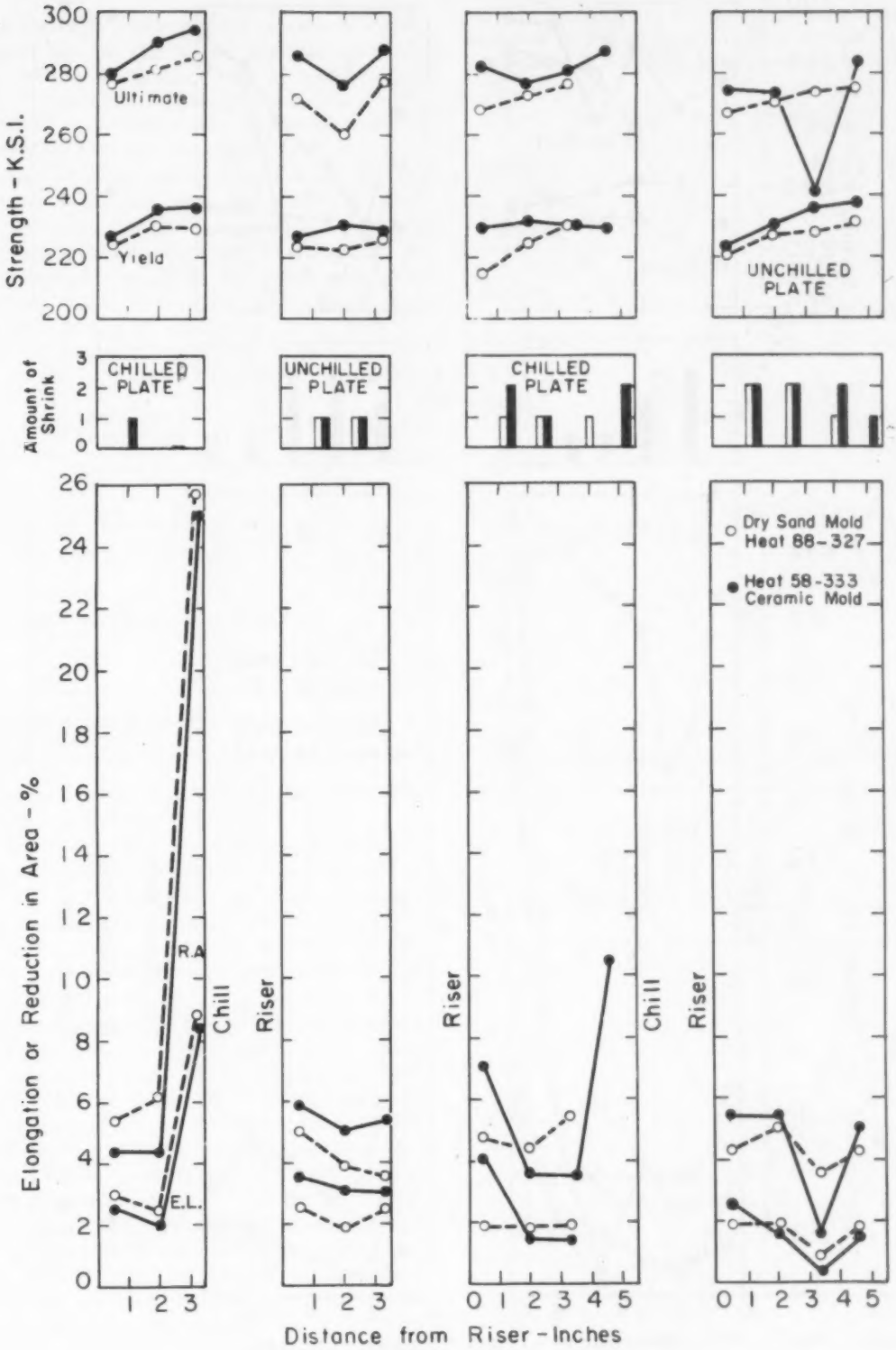


Fig. 6 — Feeding distance in 1 in. plates — 4 and 6 in. long. Test bars are 0.505 in. diameter.

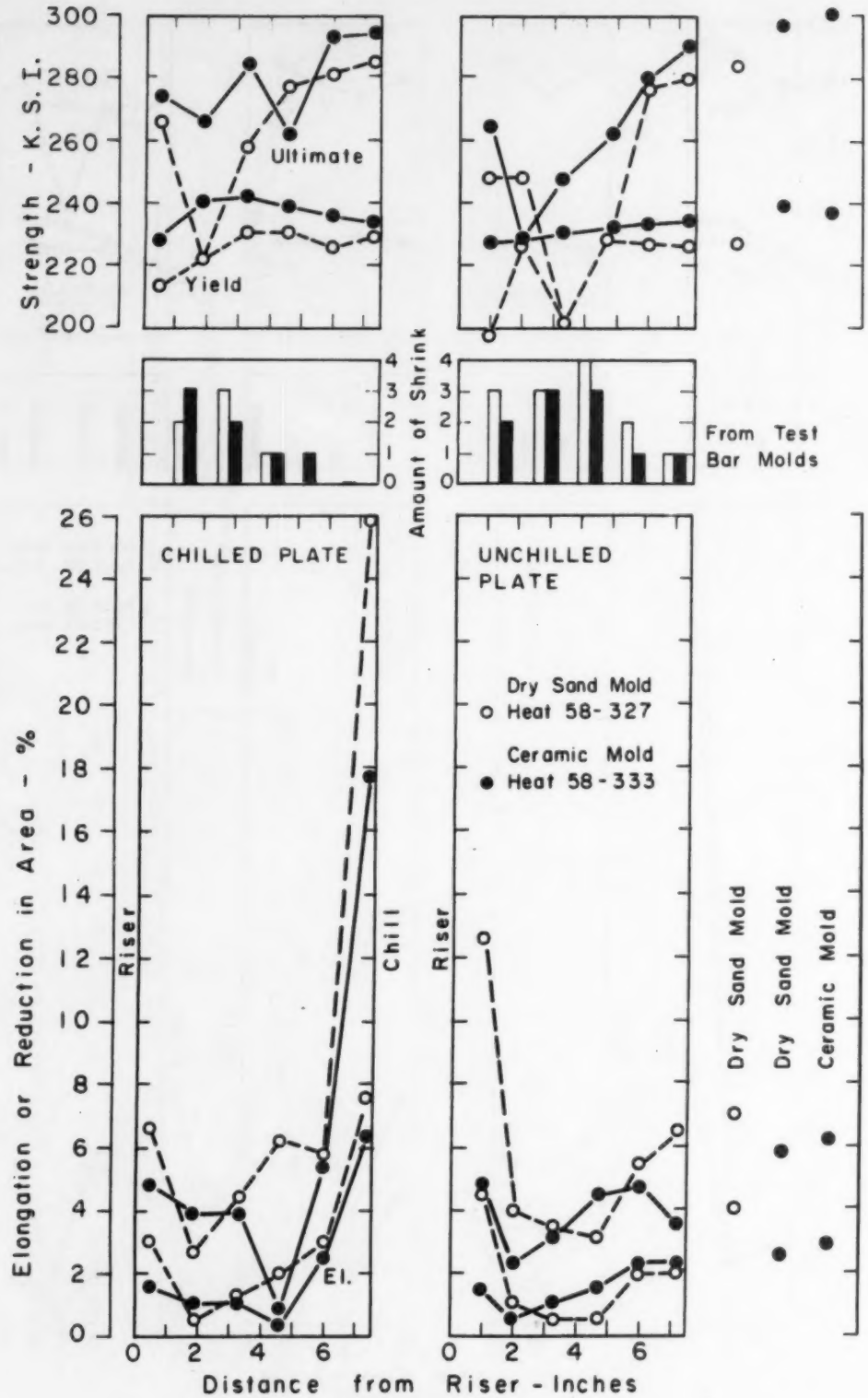


Fig. 7 — Feeding distance in 1 in. plates — 8 in. long. Test bars are 0.505 in. diameter.

bar from a plate 1 in. in thickness and 3 in. long had an elongation of 8.5 per cent at 295,000 psi tensile strength.

A quantitative description of the maximum length plate which can be cast sound depends upon an arbitrary decision as to what level of soundness or ductility is satisfactory. Table 2 shows the limits based on zero or 1 x-ray rating and another set of figures based on 2 per cent minimum elongation.

Two plates (1 x 6½ x 8 in.) from another heat of 8740 (58-368) were cast with end chills in sand molds. They were homogenized at 1850 F and oil quenched from 1575 F. One plate was tempered at 400 F and the other at 950 F. The plates were then sectioned into ⅛-in. slices which were ground into 0.020 x 0.875 x 6½ in. specimens. These were x-rayed on fine grained film and the radiographs examined for shrink at 20×. They were then pulled

TABLE 2 — FEEDING DISTANCE OF ½ AND 1 IN. PLATES

Thickness, in.	Mold Material	Unchilled Plate, in.	End Chilled Plate, in.
	Based on x-ray ratings of 1 or better		
1	Sand	4 (4T)	6 (2T+2)
1	Ceramic	4 (4T)	4 (4T)
½	Sand	2 (4T)	3 (4T+1)
½	Ceramic	2 (4T)	3 (4T+1)
	Based on 2% Minimum Elongation		
1	Sand	4 (4T)	6 *(4T+2)
1	Ceramic	4 (4T)	6 *(4T+2)
½	Sand	3 (6T)	3 (6T)
½	Ceramic	3 (6T)	4 (6T+1)

*Elongation limit relaxed somewhat since ductility in sound test bars only 2-3 per cent.

in the tensile machine. Tensile properties and radiograph results are presented in Fig. 8.

Again the properties and radiographs correlate quite well. Soundness was quite good to a distance of about 4 in. from the chill although ductility dropped off in this region. The chill probably has some benefit aside from inducing soundness; as cast grain may be smaller and microsegregation may be less in the immediate vicinity of the chill.

After the specimens were broken, the broken halves were radiographed. In every case fracture went through microshrink even when only one tiny spot was present. Most of the specimens which were completely sound broke at an angle of 45 degrees across the width of the specimen. Where unsoundness was present, the fracture was 90 degrees with respect to the length of the specimen.

Microshrinkage, although a major variable, is not the only property which changes along the length of the plate. Samples were cut from tensile specimens adjacent to the chill and the riser of the sand cast plate measuring 1 in. in thickness and 8 in. long (Heat 58-327). As shown in Fig. 9, the inclusions near the chill are small, globular and randomly distributed. Near the riser the inclusions are larger, irregular and have a tendency to be clustered.

Although in general the tensile properties correlate rather well with radiographs of thin slices, some apparent anomalies need explanation. The general characteristics of the shrinkage pattern are most apparent in Fig. 8 where a series of thin slices was cut from a 1 in. plate. Since standard tensiles were

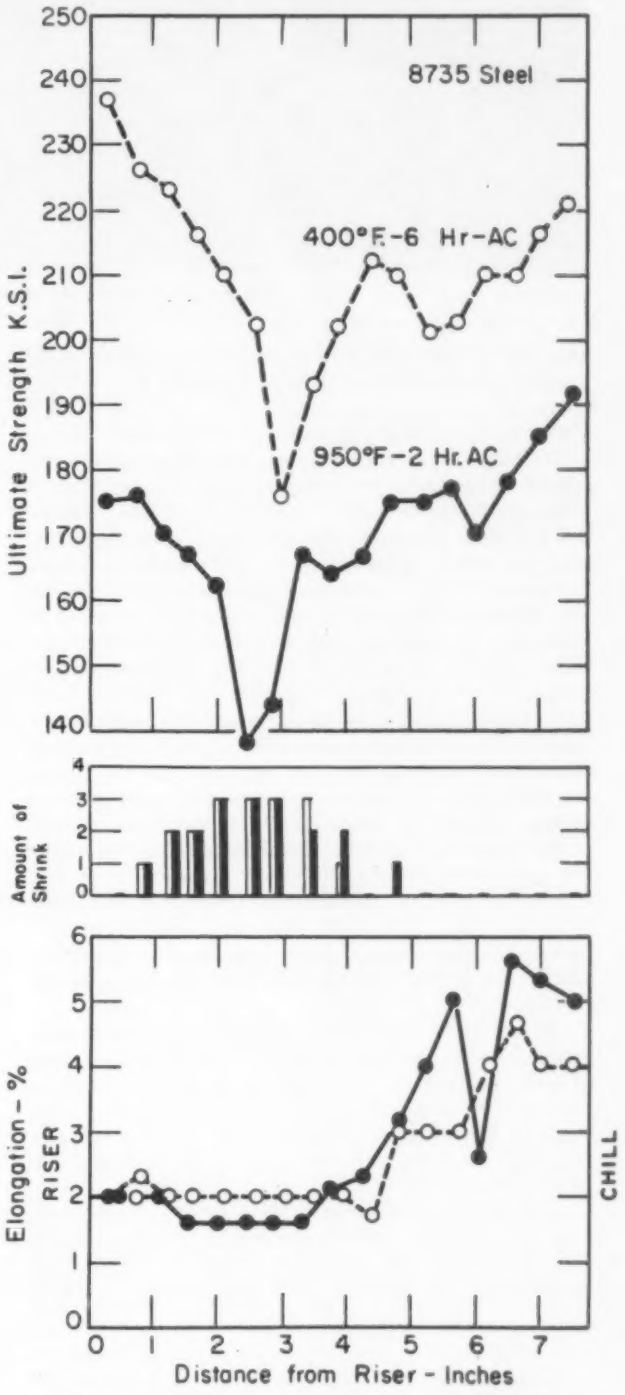


Fig. 8 — Properties in 1 in. plate — 8 in. long. Tensile specimens are 0.020 in. x 0.875 in. Heat treatment— 1800 F, 3 hr — AC; 1575 F, 2 hr — OQ. Heat no. 58-368.

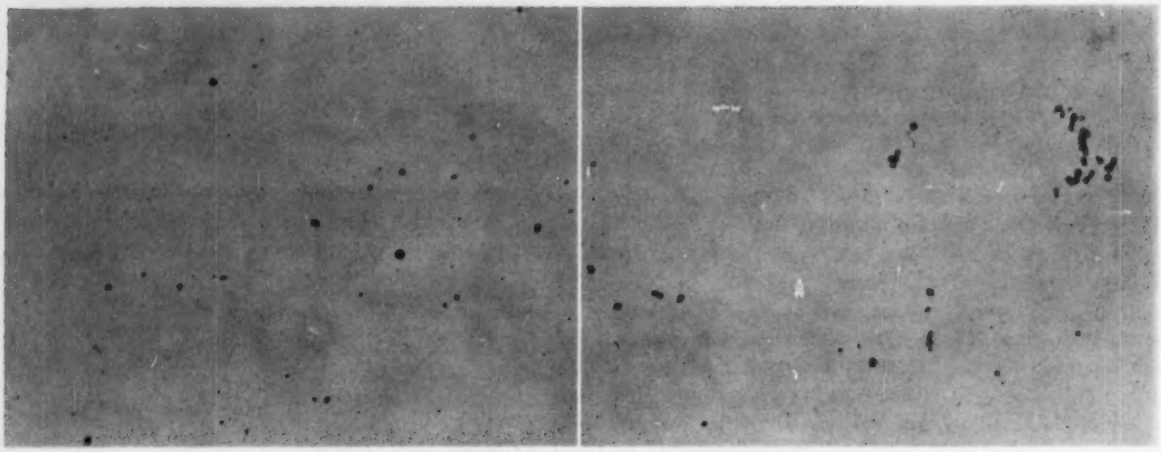


Fig. 9 — Micrographs of the chill and riser ends of plate 1 in. thick and 8 in. long. 250×. Left, chill end. Right, riser end.

not cut in this case, it was possible to obtain more and closer spaced slices than was possible in the 1 in. plates described in Figs. 5 and 7.

Sound metal was obtained over a distance of about 4 in. from the chill and in the immediate vicinity of the riser. In most of the cases described in Figs. 4 through 7, the ductility rose sharply in the vicinity of the riser, although the first x-ray slices were far enough from the riser that some unsoundness was apparent. Thus, the radiograph and tensile results do not correlate well in the immediate vicinity of the riser. Taking an x-ray slice before the first tensile specimen would have been a preferable technique.

It was surprising to obtain complete soundness in the 1 x 8 in. long ceramic molded plate by normal x-ray procedures (2 per cent sensitivity). This length of sound plate is greater than expected from Pellini's original work. Of course, his work was done in sand molds, and the difference in molding materials might be expected to cause a difference, especially since this particular type of ceramic mold gives a slower solidification rate than sand. However, the microradiographs of thin slices do not indicate any significant difference between plates poured in the two molding materials.

It should be noted that taking radiographs of thin slices in this way is a sensitive method of detecting traces of shrink. A 1 or 2 rating in Fig. 3 represents metal that is actually quite sound by normal techniques. However, as shown by Figs. 4 to 7, even this quantity of shrinkage can effect properties at these high strength levels.

Taking tensile specimens from plates in this manner can lead to unduly pessimistic conclusions. In the first place the soundest metal is removed in machining the specimen. The dotted lines in Fig. 3 show the diameter of the gage length compared to original thickness of the plate. It is obvious that the poorest metal is being tested. Also machining in this manner can put shrinkage defects at the surface of the tensile specimen where, according to observations, they have the most detrimental effect.

Finally, defects at the center may have little effect on actual performance of castings in service. In bending or torsion the presence of defects along the neutral axis would have only a minor influence. Also in fatigue type service, defects at the surface are the most important.

Although testing specimens from a casting may not give a reliable picture of quality of the casting as a structural component, these results indicate that slight traces of microshrinkage have a rather pronounced effect on the ductility of tensile specimens of cast ultra high strength steel.

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APPLICATION OF THEORY IN UNDERSTANDING FLUIDITY OF METALS

By J. E. Niesse, M. C. Flemings and H. F. Taylor

ABSTRACT

A theoretical analysis of fluidity of pure metals was carried out employing heat flow and fluid flow relationships. Equations were developed to predict fluidity of pure metals at their melting point and to predict the effect of superheat on fluidity.

An experimental investigation was conducted using the "vacuum fluidity test"; progress of metal flow was measured by high-speed motion picture photography. Fluidity tests were made on pure tin and tin-lead alloys; quantitative agreement between theory and experiment was obtained for pure tin.

Additions of lead to tin decrease fluidity markedly. Fluidity of a tin-0.01 per cent lead alloy was found to be approximately 70 cm; for a tin-0.10 per cent lead alloy it was 45 cm; and for a tin-1.0 per cent lead alloy it was 22 cm (all tests conducted at the liquidus temperature). In most other metals, small additions of alloys also decrease fluidity, and an explanation for this behavior is set forth herein. It appears that alloying elements which decrease fluidity do so by altering the mode of solidification of the pure metal.

A discussion is presented regarding the location in a fluidity spiral where solidification first chokes off liquid flow. It is concluded this solidification occurs either at the entrance to the flow channel, within the flow channel or at the tip of the flowing stream, depending (predictably) on alloy analysis and superheat.

Experiments were made on fluidity of aluminum-tin alloys and on low-carbon steel. The results obtained showed the understanding of fluidity gained from studying low melting metals was applicable to other systems. Low-carbon steel was found to have flow and solidification characteristics similar to certain of the tin-lead alloys.

INTRODUCTION

Metal "fluidity" (in the casting sense) has been defined as the property of a metal which allows it to flow freely and evenly into a mold cavity and fill it before such freezing occurs as would obstruct further flow.[1] The study of fluidity is, of course, of great practical importance, and many different tests have been developed to evaluate the various factors affecting fluidity. Almost all these tests involve one basic feature; metal is caused to flow into a mold channel of small cross-sectional area. The distance metal flows before being stopped by solidification is the measure of fluidity. Several excellent reviews of fluidity and fluidity testing may be found in the literature.[1-3]

The present work is primarily a study to determine the fundamental quantitative effects of such variables as metallurgy, fluid flow and heat flow upon fluidity. The work is, in a sense, a continuation and extension of a previous basic study in the M.I.T. foundry laboratory.[4,5] It deals with 1) an analysis of factors affecting fluidity of pure metals when heat flow rate varies with time (as in a sand mold), 2) an analysis of the effect of superheat on fluidity and 3) discussion of how alloying elements change the fluid flow characteristics and pure metals.

Experimental work, supporting the theoretical studies, has been carried out using a carefully controlled "vacuum fluidity test." Research has been devoted primarily to studies on pure tin and tin-lead alloys, but tests have also been made (using the same apparatus) on the fluidity of a low-carbon steel.

FLUIDITY OF PURE METALS

Figure 1 is a schematic diagram of metal flowing in a fluidity test piece. The metal travels down a sprue and into a thin tubular mold cavity "pushed" by the pressure head (Z_1-Z_e). There are a variety of fluid flow resistances in such a system which act to reduce the velocity of metal; these include internal friction, wall friction, etc. However, flow does not cease entirely until some section of the channel is sufficiently solid to prevent passage of further liquid.

Because it is solid metal that ultimately stops flow in a channel, rate of solidification is a factor which must be considered in any analysis of fluidity. Another equally important consideration is mode of solidification; i.e., the nature of solid grains which form and their location in the flowing stream. While much still remains to be learned about the effects of solidification variables on fluidity, several previous researches[4,6] have yielded an engineering understanding of how solidification of a pure metal takes place in a fluidity spiral. This is illustrated in Fig. 2 for a metal poured at its melting point. Subsequent

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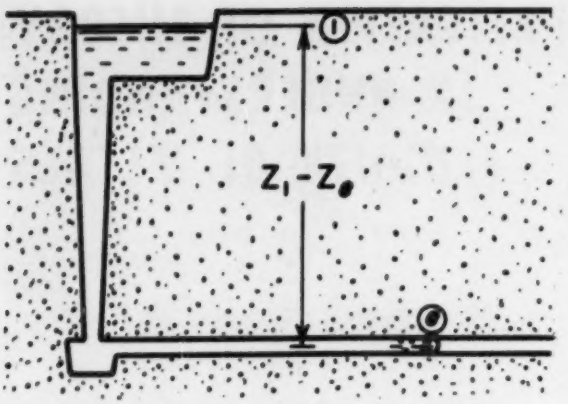

Fig. 1 — Schematic diagram of flow in a fluidity test.

analyses in this paper are based on the model of Fig. 2.

Pure Metal Solidification

As a pure metal with no superheat enters the fluidity test channel (Fig. 2), solidification must begin immediately, since heat flows from the metal into the mold. The absolutely pure metal freezes on the mold wall with a smooth liquid-solid interface, as shown in Fig. 2a. As it continues to flow downstream, solid continues to form and freeze along the wall; however, the location nearest the entrance to the flow channel began to freeze earliest, and it is here that complete solidification of the cross-section occurs first (Fig. 2c).

Certain assumptions are implicit in the above description, including conditions of radial heat flow and of no undercooling. Earlier works discuss these assumptions and present ample theoretical and experimental evidence that fluidity spirals of pure metals, poured without superheat, do in fact freeze first at the channel entrance.[4,6]

The effect of superheat on solidification of a pure metal in a fluidity spiral is sketched in Fig. 3 and discussed in detail later in this paper. Essentially, it has been concluded that superheat moves the point downstream where solid grains form and block the further flow of metal. The basic mechanism of solidification and flow stoppage, however, remains unchanged.

The following paragraphs present heat flow and fluid flow analyses which describe quantitatively the models of Figs. 2 and 3 for the various conditions expected to occur in sand molds and compare these analyses with experimental data.

Heat Flow

Consider a short length of a fluidity channel of circular cross-section wherein a pure metal is flowing and freezing (Figs. 1-3). Heat, flowing from metal to mold, must traverse 1) liquid metal to the solid-liquid interface, 2) solid-liquid interface, 3) solid metal, 4) metal-mold interface and 5) mold. Each of the preceding zones offers a barrier to heat flow, but for the various conditions encountered in ordinary fluidity tests only the last two are important.

This is so because of the high thermal conductivity of metals, the fact that much of the heat originates from heat of fusion and does not pass through the liquid and the fact that practically no specific heat is lost from the solid metal. The latter can easily be

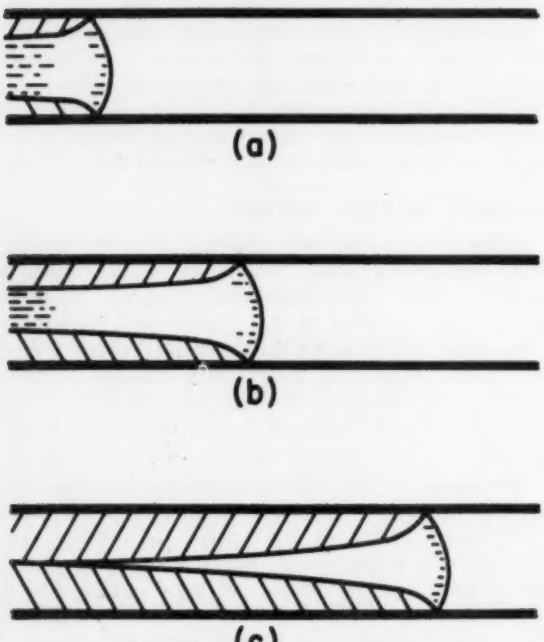

Fig. 2 — Schematic diagram of flow and solidification of a pure metal in a fluidity channel (no superheat). (a) Liquid metal enters flow channel; columnar grain formation (with smooth liquid-solid interface) begins. (b) Columnar grains continue to grow. (c) Choking off and flow cessation occurs.

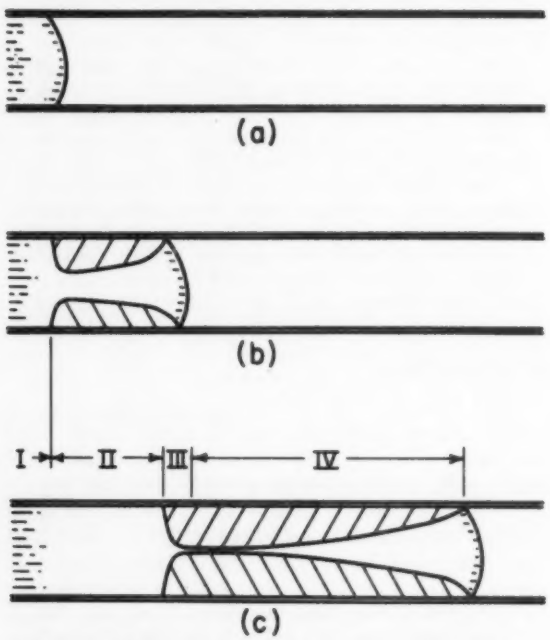

Fig. 3 — Schematic diagram of flow and solidification of a pure metal in a fluidity channel (with superheat). (a) Liquid enters flow channel and dissipates superheat before solidification begins. (b) Solidification begins by growth of columnar grains. (c) Choking off occurs.

shown by use of Adams' analysis of solidification in sand molds.[7]

In the following analysis, resistances due to the metal-mold interface and to the mold itself have been considered. Heat flow rate in the mold has been assumed to be inversely proportional to the square root of time (θ type) as is found in sand molds. The equations developed by Adams[7] apply and have been used herein. Figure 4 shows schematically the temperature distribution across a radial cross-section of a solidifying fluidity spiral, and equation (1) below is the resulting analytical expression describing heat flow as a function of time (Appendix A gives details).

$$Q = \frac{2\pi R h (T - T_r)}{B}\left[\theta_h + 2A\left(1 - \frac{1}{B}\right)\sqrt{\theta_h} - \frac{2A^2}{B}\left(1 - \frac{1}{B}\right)\ln\left(1 + \frac{B}{A}\sqrt{\theta_h}\right)\right] \qquad (1)$$

Symbols used in this and in subsequent equations are defined in Appendix B.

A typical solution of equation (1) is shown graphically in Fig. 5. Heat flow rate, dependent on mold resistance as well as interface resistance, decreases with time. Equation (1) applies to mold channels of circular cross-section in sand, although similar procedures may be used for analyzing other types of molds.

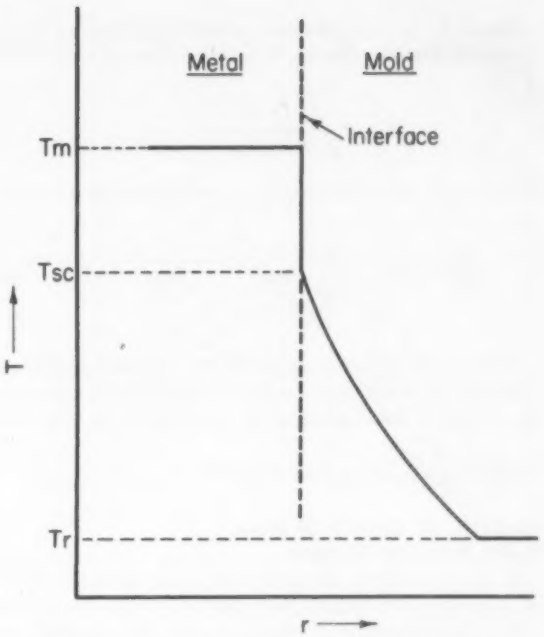

Fig. 4 — Schematic temperature distribution in metal and mold. Temperature distribution is across a radial cross-section of the fluidity spiral and into the sand or glass mold.

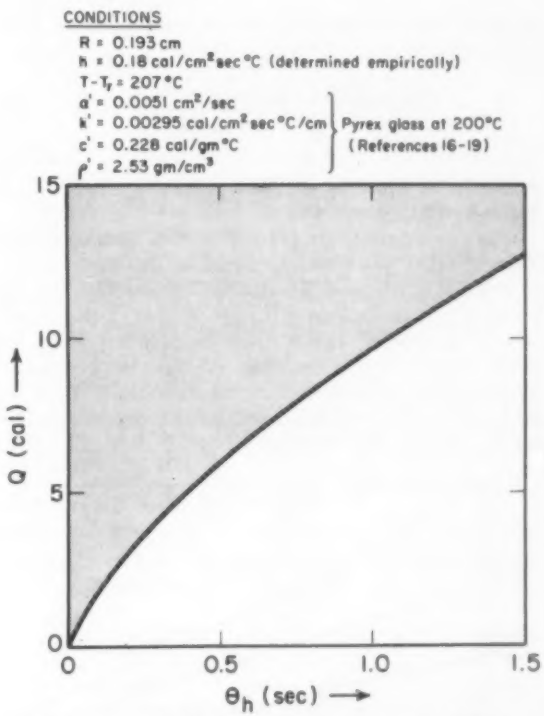

Fig. 5 — Typical heat flow curves for a cylinder mold.

Fluid Flow

To arrive at an analytical expression for fluidity it is necessary to determine fluid flow as well as heat flow characteristics. Heat flow analysis allows one to predict the rate and extent of solidification, but the incorporation of fluid flow variables is essential to determine how far the liquid metal travels before solidification imposes enough frictional resistance to stop the flow.

Consider fluid flow in the case of a pure metal flowing and freezing with a smooth solid-liquid interface. An energy balance between the leading tip of the stream (e), Fig. 1, and the free surface of liquid metal (1) supplying the fluidity channel yields:

$$2gZ = V_e^2(1 + \phi_{ent}) + \int_0^{L_e} f V^2 \frac{dl}{2r} \qquad (2)$$

where the wall friction energy is integrated over the length of the flow in the last term of equation (2).

"Z" is the "head of metal" given by:

$$Z \equiv Z_1 - Z_e + \frac{P_1 - P_e}{\rho} \qquad (3)$$

This term, Z should include effects, if any, of surface tension. However, due to the uncertainty of data, especially for alloys, these effects are neglected. The result of surface tension would be a simple decrease in Z and would have little effect on the remainder of this analysis.

Conservation of matter requires that:

$$\pi r^2 V = \pi R^2 V_e$$

$$V = \frac{R^2}{r^2} V_e \qquad (4)$$

which, substituted in the last term of equation (2), gives:

$$V_e = \sqrt{\frac{2gZ}{1 + \phi_{ent}}} \frac{1}{\sqrt{1 + \frac{fR^4}{2(1 + \phi_{ent})}\int_0^{L_e} \frac{dL}{r^5}}} \qquad (5)$$

When L_e is zero (that is, at the beginning of flow) V_e is the initial velocity V_i:

$$V_i = \sqrt{\frac{2gZ}{1+\phi_{ent}}} \qquad (6)$$

which may be substituted in equation (5) to give:

$$\frac{dL_e}{d\theta} = V_e = \frac{V_i}{\sqrt{1+\frac{fR^4}{2(1+\phi_{ent})}\int_0^{L_e}\frac{dL}{r^5}}} \qquad (7)$$

This is the general equation for fluidity with variables L_e, L, r and θ. In order to find L_e as a function of θ, r must be expressed in terms of L so that the integral $\int \frac{dL}{r^5}$ may be evaluated.

Analysis of Length of Flow If No Freezing Occurs

If no freezing occurs, as in the case of initial parts of fluidity tests when superheated metal (pure and alloys) is poured, r is equal to R, the channel radius. Then equation (7) becomes

$$\frac{dL_e}{d\theta} = V_e = \frac{V_i}{\sqrt{1+\frac{f}{2(1+\phi_{ent})R}L_e}} \qquad (8)$$

in which the variables L_e and θ are separable. Integration yields:

$$L_e = \frac{2(1+\phi_{ent})R}{f}\left[\left(\frac{3}{4}\frac{fV_i\theta}{(1+\phi_{ent})R}+1\right)^{2/3}-1\right] \qquad (9)$$

Analysis of Fluidity of Pure Metals, No Superheat

When pure metal is poured at the melting point, freezing takes place on the mold walls. The amount of solid is controlled by the heat flow; that is, the value of r may be found if θ_h is known. Using equation (1) to find Q and r, then numerically summing elements of $\Delta L : r^5$, equation (7) can be evaluated. By repeating this numerical process starting at V_e equal to V_i and continuing until the stream velocity is zero, fluidity can be determined. The Table shows the initial conditions of such a numerical process. Figure 6 shows the shape of the solid-liquid interface, and Fig. 7 the calculated variation of stream velocity V_e as flow progresses.

From analysis of Fig. 6, r is a parabolic function of L of the type

$$r = R - K\sqrt{L_e - L} \qquad (10)$$

where K is a function of V_e. For the curves of Fig. 6:

$$K = \sqrt{\frac{0.0045}{V_e - 4} - 0.00002} \qquad (11)$$

Unfortunately, this parabolic relation does not hold as the velocity approaches zero. The relationship of equation (11) is indeterminate when V_e is 4 cm/sec. For the conditions of Fig. 6, excellent agreement is obtained between the point solutions of equation (10), and curves obtained by numerical analysis until the elapsed time θ is over 1.06 sec (or until V_e is about 15 cm/sec). This is illustrated by the points plotted on Fig. 6.

CONSTANTS EMPLOYED FOR SOLUTION OF EQUATION (12)*

Conditions:	
$R = 0.193$ cm	$\rho' = 2.53$ gm/cm³ (pyrex)[19]
$h = 0.18$ cal/cm² C sec	$\rho H = 106$ cal/cm³ (tin)
$c' = 0.228$ cal/gm C[17,18]	$f = 0.04$
$k' = 0.00295$ cal/cm² sec C/cm[16]	$\phi_{ent} = 0.95$
$V_i = 180$ cm/sec	$\Delta L = 2$ cm
	$T\text{-}T_r = 207$ C

*Solution drawn in Fig. 9.

Substituting equation (10) into (7) eliminates the variable r; integration yields:

$$\frac{dL_e}{d\theta} = V_e = \frac{V_i}{\sqrt{1+\frac{fR}{12K^2(1+\phi_{ent})}\left(1+\frac{4\frac{K}{R}\sqrt{L_e}-1}{\left(1-\frac{K}{R}\sqrt{L_e}\right)^4}\right)}} \qquad (12)$$

Equation (12) can be solved numerically from $V_e = V_i$ to $V_e = 15$ cm/sec. At the latter point the

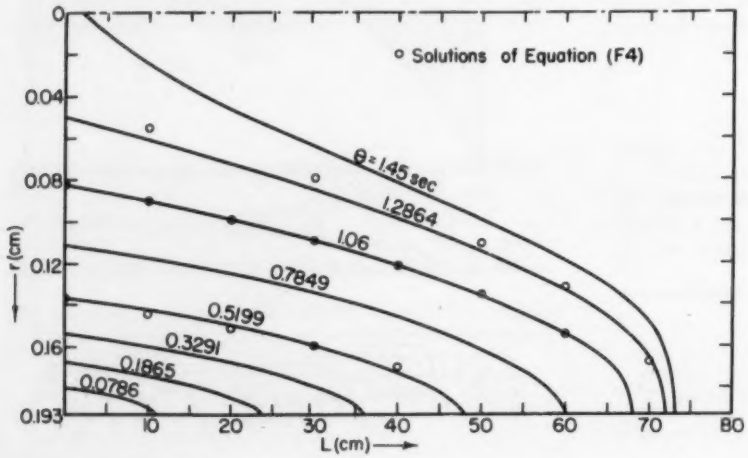

Fig. 6 — Solid-liquid interfaces for $V_i = 180$ cm/sec. Curves calculated for pure tin poured at its melting point into a fluidity test channel 0.386 cm in diameter.

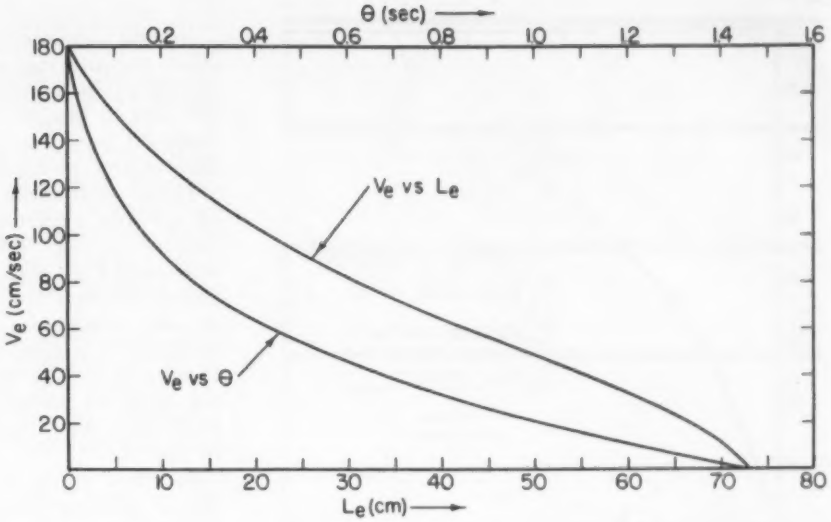

Fig. 7 — Stream velocity as a function of time θ and length L_e. Curves calculated for pure tin poured at its melting point into a mold 0.386 cm in diameter.

metal stream has completed about 95 per cent of its total flow length.

Superheat Effect on Fluidity of Pure Metals

Figure 3 illustrates qualitatively the effect of superheat on fluidity of a pure metal. Essentially, superheat prevents solidification from occurring near the entrance to the flow channel so that choking off of metal flow occurs further downstream and at a later time. Experimental evidence indicates this does, in fact, occur.[6]

Employing the assumptions made earlier in this paper, it is possible to describe in more detail the effects of superheat and to derive a mathematical expression covering a particular case. The assumptions that liquid metal cannot support a significant temperature gradient and that superheated liquid and solid metal cannot coexist for any length of time are employed. This appears to be realistic since flow of the liquid metal is highly turbulent and heat diffusivity of metals is high.

During flow of a superheated metal in a fluidity spiral there exists as many as four distinct zones (Fig. 3c):

I) A zone where no freezing occurs.
II) A zone where freezing once occurred but where superheated metal has caused re-melting so that no solid remains.
III) A zone where solid exists but remelting is occurring.
IV) A zone where solidification is progressing.

When the first metal enters a fluidity channel, it flows without freezing until its superheat is dissipated; the length to the point where solidification begins constitutes zone I. Subsequent small sections of metal which travel down the spiral do not dissipate their heat so rapidly since rate of heat flow into the mold decreases with time at any one location. The small sections of liquid arrive at the beginning of the partially solid zone with some superheat remaining; they therefore remelt this solid in the region termed zone III. At any instant of time the length that has been completely remelted is zone II. In zone IV, liquid and solid coexist (both at the melting point) and solidification takes place exactly as in the case of metal poured at its melting point.

On the assumptions that heat flow is radial and that thermal gradients in the liquid are small, zone III must be of negligible length. Then, with zones I and II identical from a friction-loss standpoint, equation (7) becomes

$$\frac{dL_e}{d\theta} = V_e = \frac{V_i}{\sqrt{1+\frac{fR^4}{2(1+\phi_{ent})}\left[\frac{L_1}{R^5}+\int_{L_1}^{L_e}\frac{dL}{r^5}\right]}} \qquad (13)$$

Where L_1 is the distance from the channel entrance to the beginning of solid metal.

Using equation (10), r may be eliminated and the friction integral evaluated:

$$\frac{dL_e}{d\theta} = V_e = \frac{V_i}{\sqrt{1+\frac{fR^4}{2(1+\phi_{ent})}\left[\frac{L_1}{R^5}+\frac{1}{6K^2R^3}+\frac{4K\sqrt{L_e-L_1}-R}{6K^2(R-K\sqrt{L_e-L_1})^4}\right]}} \qquad (14)$$

Unfortunately, to evaluate equation (14), a laborious numerical procedure is required. Equation (13) must first be solved to determine how L_1 and K are related to θ, L_e and V_e.

Comparison With Experiment

Experimental data for fluidity of a pure metal were obtained using the vacuum fluidity test developed by Ragone, Adams and Taylor.[5] In this test (Fig. 8)

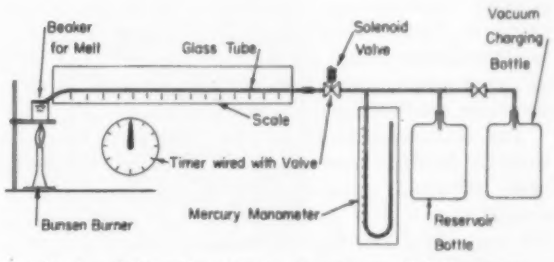

Fig. 8 — Schematic sketch of vacuum fluidity apparatus.

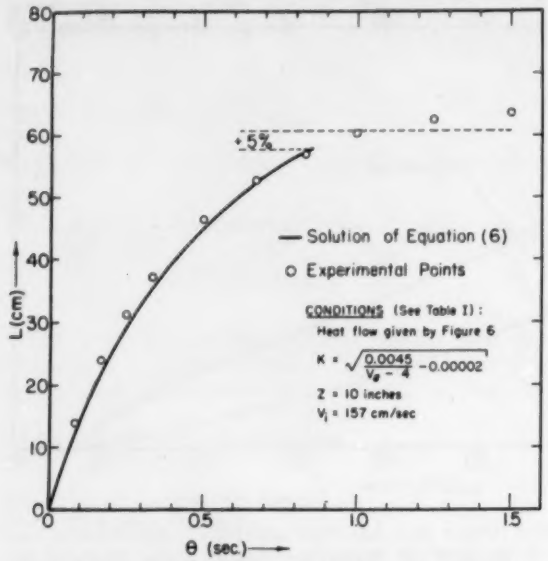

Fig. 9 — Curves of fluidity L vs. time θ comparing analytical, equation (6), to experimental results. Experimental results obtained for pure tin poured at its melting point into a test channel 0.386 cm in diameter, and under 10 in. of metal head.

liquid metal is drawn into a glass tube by a partial vacuum. Advantages of the test compared to other fluidity tests include 1) close control over many mold and fluid flow variables, 2) ability to perform many tests quickly and reproducibly and 3) opportunity to photograph metal flow with a high-speed motion picture camera. In addition, heat flow characteristics of the glass mold are quite similar to those of a sand mold.

Figure 9 illustrates experimental data for fluidity of highly pure tin at its melting point compared with a calculated curve. The calculated curve is based on equation (12) using the constants shown in the Table, except that initial velocity is 157 cm/sec corresponding to a metal head Z of 10 in. Comparison between calculated and experimental values is good up to the limitation of equation (12); this limitation is at approximately 95 per cent of the total length.

FLUIDITY OF ALLOYS

General Discussion

In the absence of undercooling effects, absolutely pure metals freeze with a smooth "plane front" interface between the solid and liquid. This mechanism of solidification is illustrated in Figs. 2 and 3. When alloying elements are added to a pure metal, the metal no longer solidifies with a smooth interface; small additions cause the front to become "rippled," or "corrugated," and with slightly larger additions dendrites reach out into the flowing stream.

The conditions which cause transition from plane front to dendritic growth in solidifying castings have been discussed qualitatively and quantitatively by several authors.[8-10] Briefly, these conditions include the amount of alloying element, type of alloy system, characteristics of alloying element and thermal gradients in the casting.

In most alloy systems small amounts of alloying elements are sufficient to bring about dendritic growth during solidification. In some systems, less than 0.01 per cent by weight is adequate, and in the present study 0.1 per cent lead dissolved in tin was more than enough to break the plane front.

Figure 10 illustrates the effect that small amounts of alloying elements have on solidification in a fluidity casting. Solidification and flow stoppage mechanisms are similar to that illustrated in Fig. 2, except that here the solidification front is no longer smooth. Dendrites project into the flowing stream, and friction is much greater than it would be in the absence of such projections. Small amounts of alloying elements almost always decrease fluidity of a pure metal by affecting solidification, as illustrated in Fig. 11.

In alloys which contain somewhat higher percentages of alloying element than that illustrated in Fig. 10, dendrites may reach even further into the stream and create such high friction that metal flow ceases when only a small fraction of any cross-section is completely solid. Based on this assumption (that flow ceases after only a negligibly small amount of solidification takes place) Rightmire and Taylor[11] have analyzed and successfully correlated a large amount of experimental data on fluidity of cast steels.

Equiaxed Dendritic Solidification

There is another type of solidification which is known to occur in fluidity test castings. Alloys which contain a substantial percentage of solute, and in which nucleation is not a problem, solidify with equiaxed dendrites.[6,12] As the equiaxed grains form and

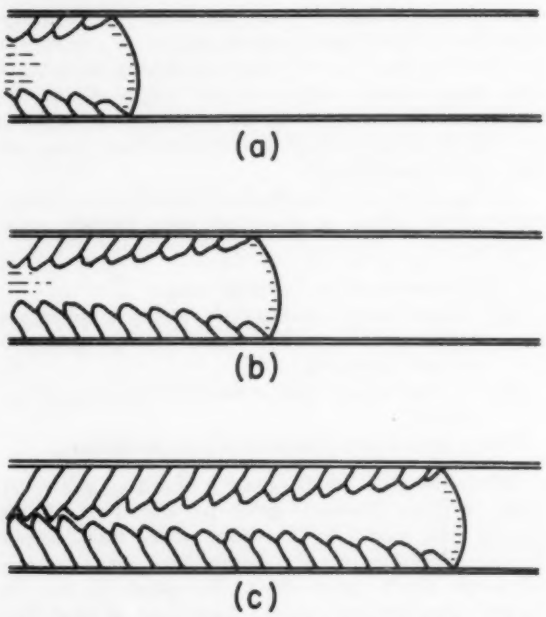

Fig. 10 — Schematic diagram of flow and solidification of a dilute alloy in a fluidity test channel (no superheat). (a) Liquid enters flow channel; columnar grain formation with jagged liquid-solid interface begins. (b) Columnar grains continue to grow. (c) Choking off occurs at flow channel entrance, cross-section is not completely solid but is sufficiently solid to prevent flow.

grow, they flow downstream until frictional effects become large enough to stop flow. The degree of this friction has been shown to depend on the size and shape of the solid particles as well as on the amount of solid.[12]

When the solid is growing in dendrite-like shapes, small percentages of solid can effect flow stoppage; Fig. 11 illustrates this mechanism schematically. Fine grains form at the tip and flow downstream. Metal flow is eventually choked off at the tip of the stream when frictional effects due to the solid grains become sufficiently high.

Figures 12 and 13 present macrostructures taken from fluidity spirals of two aluminum-tin alloys; these structures illustrate the two mechanisms of solidification described above. In Fig. 12 (aluminum containing 0.1 per cent impurities) columnar dendrites formed and grew on the mold wall. These dendrites choked off flow at a point near the entrance of the fluidity spiral. In Fig. 13, illustrating the macrostructure of an aluminum-10.0 per cent tin alloy, fine grains formed and traveled downstream with the flowing metal. More detailed discussion of flow and solidification of these alloys can be found in the original sources from which Figs. 12 and 13 were abstracted.[6,13]

Earlier in this paper a model was presented which described solidification of a pure metal in a fluidity test casting (Figs. 2 and 3). This model lent itself to

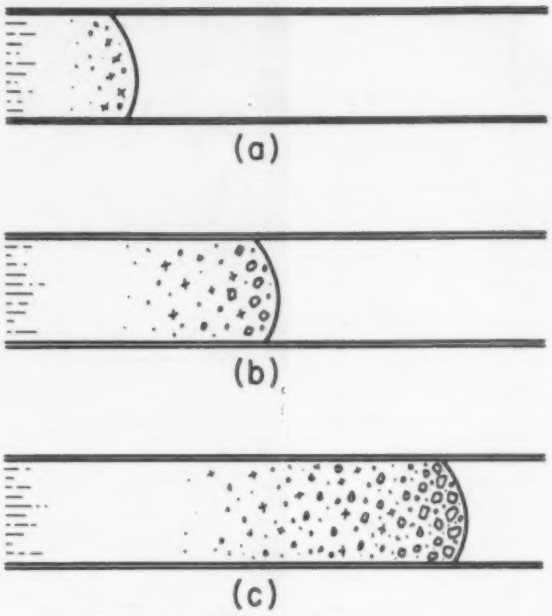

Fig. 11 — Schematic diagram of flow and solidification of an alloy which readily nucleates fine grains (no superheat). (a) Liquid enters flow channel, fine grains nucleate at the tip. (b) Nucleation continues and fine grains grow rapidly as flow progresses. (c) Flow ceases when a critical concentration of solid grains is attained at the tip.

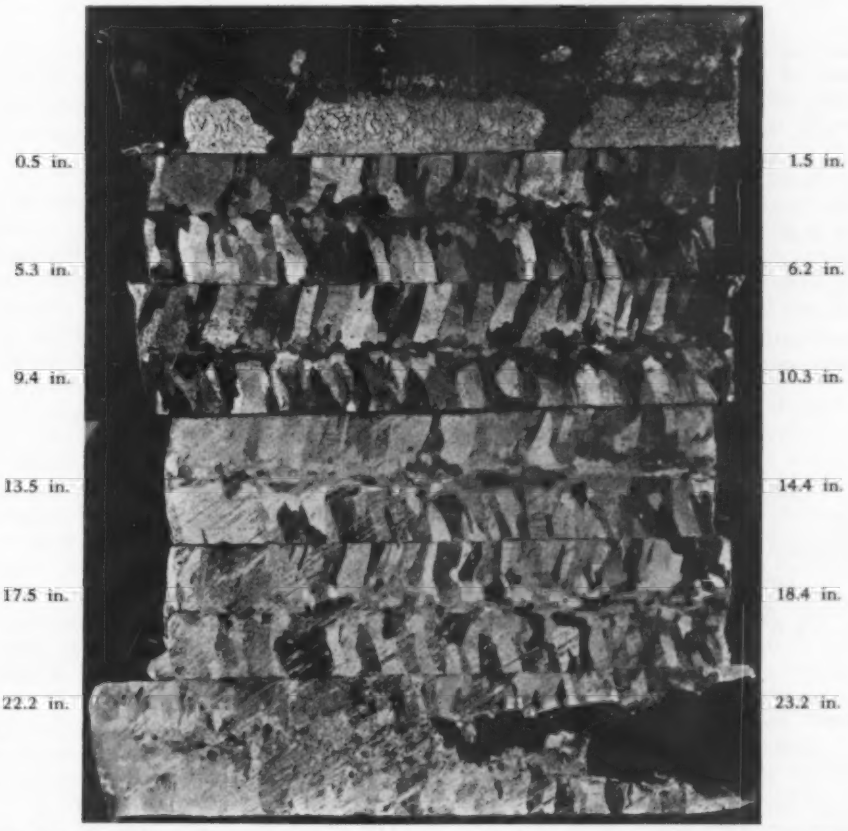

Fig. 12 — Longitudinal macrostructures of an aluminum (99.99 per cent) fluidity casting. Temperature, liquidus plus 150 F (83 C); metal flow left to right. Figures at sides represent distance along the tube.[6,13] 4×.

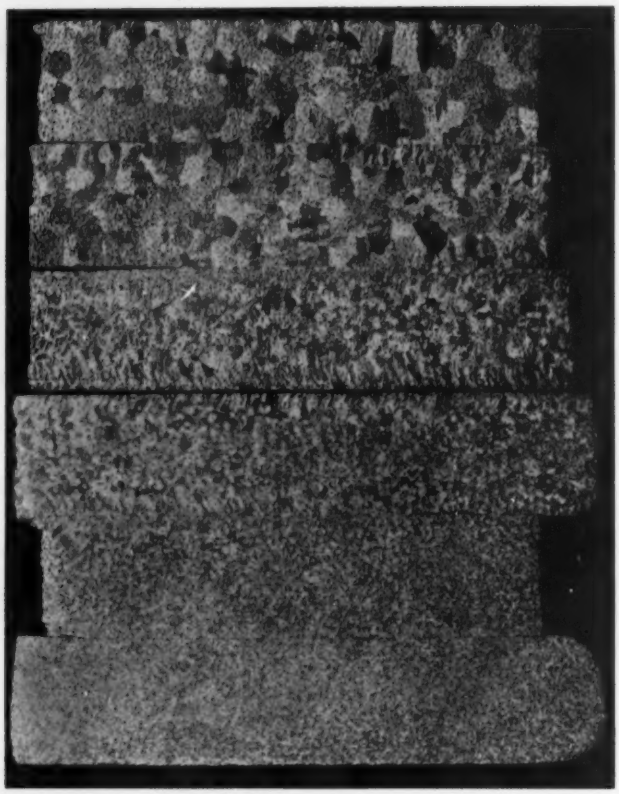

Fig. 13 — Longitudinal macrostructures from an aluminum-5.0 per cent tin fluidity casting. Temperature, liquidus plus 147 F (82 C); metal flow from left to right. Figures at sides represent distance along the tube.[6,13] 4×.

mathematical analysis, and equations were developed from this analysis for fluidity of pure metals. The models which have been drawn for alloys (Figs. 10 and 11) do not lend themselves as readily to mathematical treatment primarily because friction effects are difficult to evaluate. This is so because it is difficult to determine quantitatively 1) total flow area available between dendrites which adhere to the mold wall, 2) roughness of these dendrites and 3) increased friction resulting from fine grains which flow downstream with the metal.

Therefore, quantitative analysis of the fluidity of alloys has not been undertaken in this work. The remainder of this paper presents experimental results illustrating the effect of alloying on fluidity and fluid flow and illustrating the applicability of models for understanding the flow behavior of alloys.

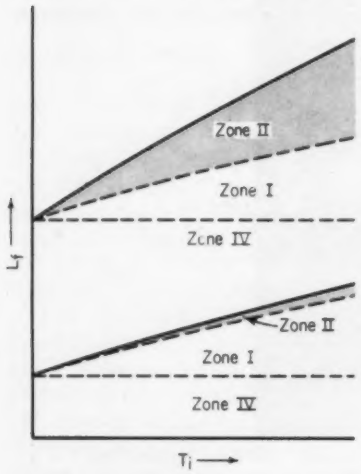

Fig. 14 — Schematic curves showing increased influence of zone II with increased fluidity.

Superheat Effect

Because the mechanism of freezing cannot be put in fully quantitative terms, only a rough analysis of the effect of superheat on fluidity can be made. Referring again to Fig. 3, fluidity test castings are considered to be made up of four distinct zones. These zones apply to alloys which solidify, as illustrated in Figs. 10 and 11, as well as to pure metals.

For both pure metals and alloys, the extent of zone I depends primarily on degree of superheat. The extent of zone II, however, depends primarily on the length of time during which liquid flows through zone I; this time is, of course, the fluid life. As a result, superheat is effective in increasing fluidity of alloys which are already highly fluid at their melting point (or liquidus temperature). The superheat increases zone I, but substantially increases zone II because of the large amount of remelting.

Conversely, superheat is not as effective in increasing fluidity of alloys which are sluggish at their liquidus; the superheat may increase zone I as much as in the case of the highly fluid alloy, but the increase of zone II is small. This situation is depicted schematically in Fig. 14; the greater the initial fluidity, the greater the effect of superheat on the fluidity. The effect has been observed by other investigators[5,6,14,15] but has not been previously explained;

experimental results showing the effect are also presented later in this paper (Fig. 16).

Experimental Results and Discussion

The vacuum fluidity test (Fig. 8) was used for all experimental work described herein. Work was devoted primarily to study of tin-lead alloys, but limited data are also presented for an aluminum-tin alloy and for a low-carbon steel.

Figure 15 illustrates the effect of alloy additions on metal fluidity. The data are for lead added to tin, and are plotted on a logarithmic scale to more clearly illustrate the effects of small additions. Additions up to about 0.07 per cent lead had little effect on fluidity (length of flow) or on fluid life (duration of flow as measured by motion picture photography). Additions over about 0.07 per cent lead sharply decreased fluidity.

It appears that there is a critical purity affecting fluidity; metals more pure than this critical composition are not much more fluid, but less pure metals are much less fluid. The explanation for this behavior lies in the fact that a change in the mode of freezing due to alloying occurs at a critical composition which depends also on the particular conditions of the test. The change in the mode of freezing in these nearly-pure metals is a change from plane front (typical of pure metals where the solid-liquid interface is an isotherm) to a dendritic type of freezing.

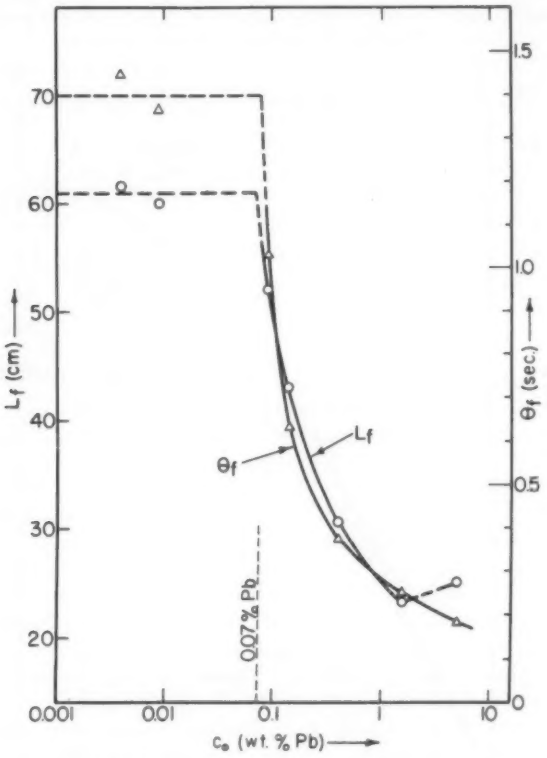

Fig. 15 — Fluidity and fluid life as a function of log composition of weight per cent lead in pure tin. In practice, several tests were conducted at temperatures slightly above the liquidus and results extrapolated to the liquidus for presentation. All runs were conducted in glass tubes 0.386 cm in diameter under a metal head of 10 in.

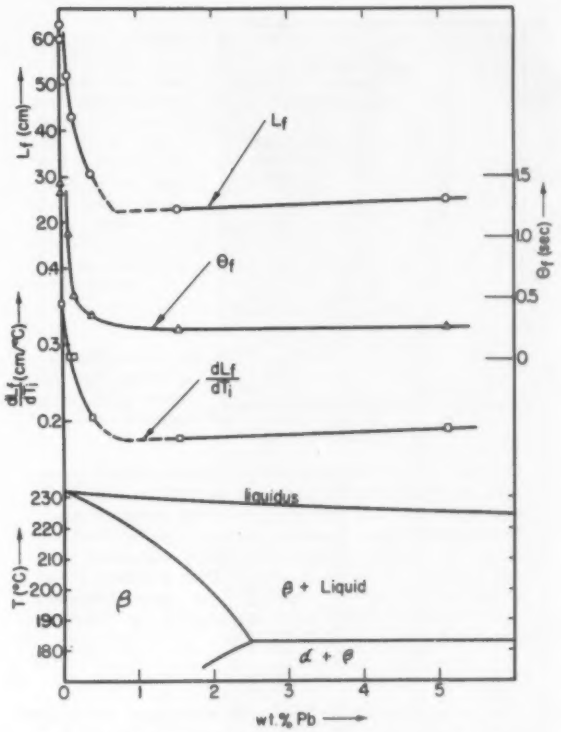

Fig. 16 — Fluidity, fluid life and slope of fluidity-temperature curve as a function of composition of weight per cent lead in pure tin at the liquidus temperature.

Figure 16 presents the fluidity data of Fig. 15 in more conventional fashion. Also shown are 1) phase diagram for the alloy system, 2) fluid life (θ_f) of the alloys studied and 3) the slope ($dLf:dt_i$) of the fluidity vs. superheat curves for the alloys. The shape of the fluid life curve is similar to that of the fluidity curve. The temperature coefficient of fluidity ($dLf:dt_i$) decreases with decreasing fluidity for reasons outlined, shown schematically in Fig. 14.

Solidification Mechanisms

Two quite different mechanisms have been discussed whereby solidification of alloys may occur in a fluidity test. In both cases growth is dendritic, but in one the solid which forms adheres to the mold walls, in the other it moves downstream. The mechanism of solidification which actually occurs for a given alloy is of importance in determining certain fluidity data, particularly fluid life as described in the following paragraphs.

If solid metal adheres to the mold walls, then fluid life (extrapolated to the melting point) should remain the same regardless of metal head, This is so because in the absence of superheat, rate of solidification and hence, fluid life are dependent only on mold and metal physical constants, not on amount of liquid flowing. For alloys in which the solid travels downstream (Fig. 11) fluid life should decrease with increasing metal head (even though fluidity increases). This apparent anomaly is explained by

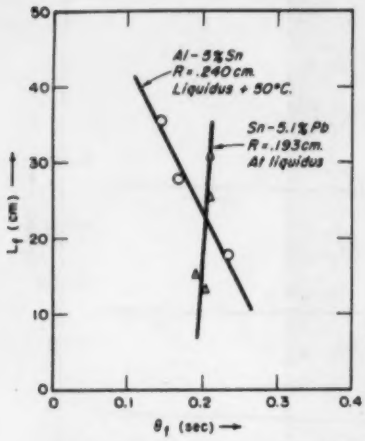

Fig. 17 — Fluidity vs. fluid life for alloys at or near liquidus temperature.

Data for lead-tin alloys are at the liquidus temperature; data for aluminum-tin alloys are at liquidus plus 50 C. Fluidity (L_f) was varied by varying pressure head. For lead-tin alloys pressure head was varied from 3.5 in. to 20 in.; for aluminum-tin alloys pressure head was varied from 10 in. to 100 in. Data for the tin-lead alloys apply to glass tubes 0.386 cm inside diameter; data for the aluminum-tin alloys apply to tubes of 0.480 cm inside diameter.

the fact that the heat flow rate decreases with time, and thus the tip of the flowing stream is always exposed to the highest cooling rate or chill. Increasing the flow velocity increases the chill which the tip experiences so the stream will freeze earlier even though it flows farther.

In Fig. 17, fluidity is plotted vs. fluid life for a tin-5.1 per cent lead alloy and for an aluminum-tin alloy. Data are for constant pouring temperature; fluidity (L_f) was varied by varying the pressure head.

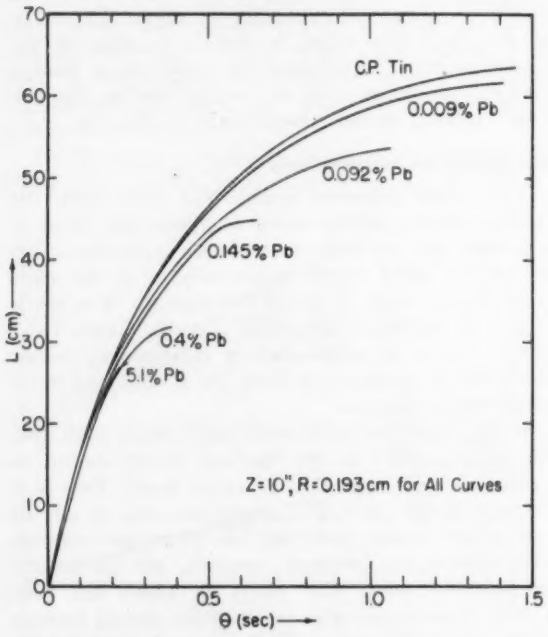

Fig. 18 — Distance L vs. time θ for tin-lead alloys at 469 F (240 C) pouring temperature.

Fluid life (θ_f) was determined by motion picture photography. Fluid life of the lead-tin alloy does not vary appreciably over the range of different metal heads employed. This behavior indicates that solidification occurred near the flow channel entrance by a mechanism similar to that of Fig. 10.

By employing the heat flow relation, equation (1), and the fluid life from Fig. 17, it was calculated that only 25 per cent of the cross-section at the flow channel entrance was solid at the end of the flow. Because this solid was in the form of a network of dendrites this small amount was able to effect flow stoppage.

The data for fluidity vs. fluid life of aluminum-5 per cent tin alloy are included in Fig. 17 for comparison. Here, fluid life decreases with increasing metal head indicating the solidification occurred by a different mechanism, typical of that illustrated in Fig. 11.

Lead-Tin Alloy Fluidity

Figure 18 shows the fluidity runs of a series of lead-tin alloys. Significant is the difference in character of the curves for the different alloys. Pure tin gradually slows down as the solid metal grows into the liquid. For 5.1 per cent lead, the flow velocity is essentially constant until flow stoppage occurs quite suddenly. The sudden stop indicates a rapid increase in friction near the end of flow due to growth of mesh-like dendrites.

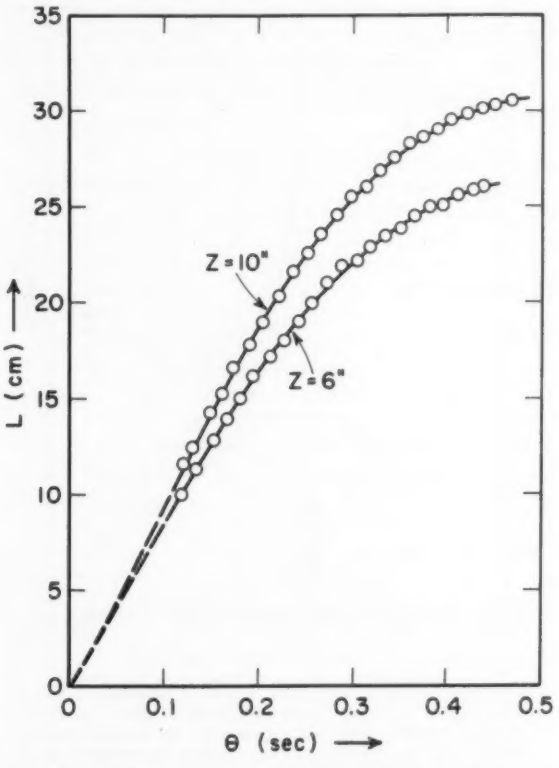

Fig. 19 — Distance vs. time curves for two fluidity tests of low carbon steel at 2837 F (1558 C). Test conducted with glass tubes 0.508 cm inside diameter.

Figure 19 is a similar recording of distance vs. time curves for two fluidity tests on low-carbon steel (0.25%, 0.43% Si, 0.6% Mn, 0.010% P, 0.04% S). The curves gradually slope off indicating a continuous increase of friction such as would be expected in a pure metal or dilute alloy. Even though the metal head was increased from 6 to 10 in., the fluid life changed only from 0.44 to 0.47 sec indicating a mechanism wherein flow stoppage occurs by solid adhering to the mold wall near the entrance to the flow channel (Fig. 10). That this was, in fact, the case was substantiated by radiographs of several of the fluidity test castings, Fig. 20.

The leading tips of the castings exhibited pipes, and the radiographs show that centerline shrinkage extended from the tip back to a location near the flow channel entrance. It was, therefore, at a point near the entrance that choking off of metal occurred; this point was slightly downstream from the entrance because of some superheat. It is of interest to note that the *V* pattern of shrinkage indicates some metal feeding took place (after flow stoppage) in a direction the reverse of original metal flow.

The preceding brief investigation of fluidity of low-carbon steel was conducted primarily to establish that theoretical studies and experiments utilizing low melting alloys yielded information which would facilitate understanding fluidity of higher melting, more widely used alloys. This objective has been realized; for example, the fluidity of low-carbon steel has been shown to be analagous in many ways to fluidity of a tin alloy containing the order of 0.1 per cent lead.

It is the expectation of the authors that the gradual acquisition of fundamental information pertaining to fluidity, such as that contained herein, will someday enable close control of the many factors affecting fluidity and fluid flow. Such control in casting quality should make it possible to produce intricate thin section castings of types that cannot be successfully cast today.

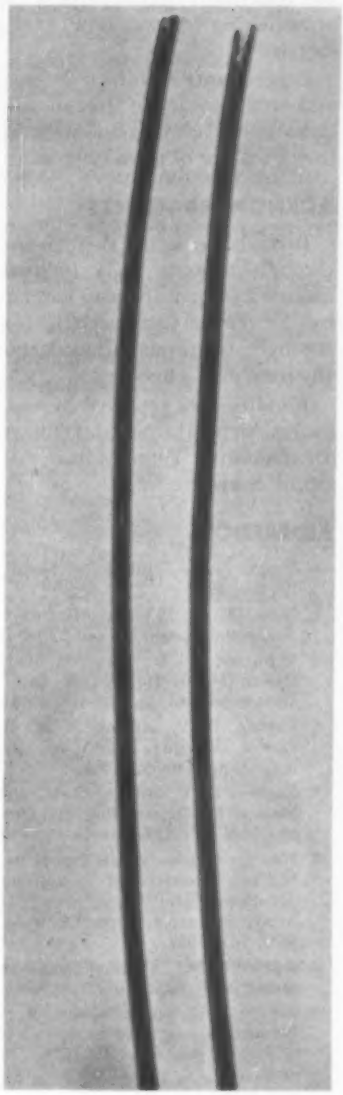

Fig. 20 — Radiographs of two typical low carbon steel fluidity castings, actual size. Note "pipe" at the leading tip (top) of the casting, with centerline shrinkage extending nearly back to the channel entrance.

CONCLUSIONS

The importance of heat flow and fluid flow factors on fluidity of metals was expressed quantitatively; and compared with experimental observations of fluidity of pure tin, tin-lead alloys, aluminum tin alloys and a low-carbon steel.

Theoretical analysis of fluidity of pure metals showed that for sand or glass molds (where heat flow rate decreases with time) the interface between solid metal and the flowing liquid is parabolic in shape.

For pure metals, the interface between solid and flowing liquid is smooth and fluidity can be evaluated quantitatively; for alloys, freezing is dendritic and quantitative analysis of fluidity would be much more difficult.

Small additions of lead to tin (above about 0.07 per cent) decrease fluidity markedly. Fluidity at the liquidus temperature of tin-0.01 per cent lead alloy was approximately 70 cm; fluidity of tin-0.1 per cent lead was 45 cm; and of tin-1.0 per cent lead, 22 cm.

Mode of solidification accounts for most of the differences in fluidity resulting from varying the alloy content of a metal. Pure metals freeze with smooth solid-liquid interfaces, and long times are necessary for the freezing of enough solid to offer substantial resistance to liquid flow; pure metals have high fluidity. Alloys freeze dendritically, and a relatively small amount of solid is able to prevent passage of further liquid; such alloys have lower fluidity. It was found that only 25 per cent solid in the entrance area of a test channel was sufficient to stop the flow of a tin-5.1 per cent lead alloy.

Flow stops in a fluidity test when some point is sufficiently solid to prevent passage of further liquid. This point may be at the entrance to the test channel, within the flowing stream or at the forward tip of the stream, depending (predictably) on alloy analysis and superheat.

Superheat is more effective in improving fluidity of pure metals than in improving fluidity of alloys. Reasons for this were analyzed theoretically, and it

was concluded that superheat caused a greater degree of remelting (during flow) in fluidity spirals of pure metals.

Experiments conducted on aluminum-tin alloys and on a low-carbon steel showed the results of earlier quantitative evaluations were applicable to the fluid flow behavior of these systems.

ACKNOWLEDGMENTS

Initial work of this program was conducted through support of a fellowship from Crane Co. awarded John E. Niesse. Later phases were supported by Air Force Contract 04(645)-9, Subcontract 7322, through Instrumentation Laboratory, Massachusetts Institute of Technology.

Fluidity data reported herein for the aluminum-tin system were abstracted from research performed by Dr. Sebastian Feliu Matas; this work is reported in detail elsewhere.[6,13]

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APPENDIX A

HEAT FLOW ANALYSIS FOR CYLINDRICAL CASTINGS

This heat flow analysis for cylindrical castings in molds such as sand may be made if one assumes that no resistance to heat flow occurs in the metal. The temperature distribution is represented in Fig. 5. Then, the heat flow rate at the metal-mold interface is given by:

$$q = 2\pi R h (T - T_{sc}) \qquad (A1)$$

Adams' equation[7] for heat flow rate into an "infinite" cylindrical mold is:

$$q = 2\pi R (T_{sc} - T_r) k' \left[\frac{1}{2R} + \frac{1}{\sqrt{\pi \alpha' \theta_h}}\right] \qquad (A2)$$

The unknown temperature, T_{sc}, may be eliminated by rearranging and then adding equations (A1) and (A2):

$$(T - T_r) = q\left[\frac{1}{2\pi R h} + \frac{1}{2\pi R k'\left(\frac{1}{2R} + \frac{1}{\sqrt{\pi \alpha' \theta_h}}\right)}\right] \qquad (A3)$$

Using $\alpha' = \frac{k'}{\rho' c'}$ and rearranging yields:

$$\frac{dQ}{d\theta} = q = 2\pi R h (T - T_r) \left[\frac{\sqrt{\theta_h}}{\left(1 + \frac{2Rh}{k'}\right)\sqrt{\theta_h} + \frac{2R}{\sqrt{\pi \alpha'}}} + \frac{\frac{2R}{\sqrt{\pi \alpha'}}}{\left(1 + \frac{2Rh}{k'}\right)\sqrt{\theta_h} + \frac{2R}{\sqrt{\pi \alpha'}}}\right] \qquad (A4)$$

for simplification let:

$$\left.\begin{aligned} A &= \frac{2R}{\sqrt{\pi \alpha'}} \sec\tfrac{1}{2} \\ B &= \left(1 + \frac{2Rh}{k'}\right) \end{aligned}\right\} \qquad (A5)$$

Equation (A4) is a differential equation in terms of Q and θ_h. Separating the variables and integrating between the limits O to Q and O to θ_h yields:

$$Q = \frac{2\pi R h (T - T_r)}{B} \left[\theta_h + 2A\left(1 - \frac{1}{B}\right)\sqrt{\theta_h} - \frac{2A^2}{B}\left(1 - \frac{1}{B}\right) \ln\left(1 + \frac{B}{A}\sqrt{\theta_h}\right)\right] \qquad (A6)$$

Equation (A6) defines the heat entering the mold as a function of time. All of the physical properties in equation (A6) may be found from published data, except h which must be determined empirically (A value of $h = 0.18$ cal/cm² C sec was found for tin freezing in glass tubes of inside diameter of 0.386 cm).

APPENDIX B

DEFINITION OF SYMBOLS

$A = 2R/\sqrt{\pi \alpha'}$ sec$^{1/2}$

$B = \left(1 + \frac{2Rh}{k'}\right)$

c' = Specific heat of mold material cal/gm C

D = Diameter of mold channel, cm

f = Friction factor

g = Acceleration due to gravity cm/sec^2

h = Heat transfer coefficient at metal-mold interface, cal/°C cm^2 sec

H = Heat of fusion of metal, cal/gm

k' = Thermal conductivity of mold, cal/sec cm^2 °C/cm

L = Length along metal stream from mold channel entrance, cm

L_e = Length to end of metal stream, cm

L_f = "Fluidity" or final length of metal stream, cm

q = Heat flow rate, cal/sec

Q = Total heat entering mold material per unit length in time θ_h, cal/cm^2 sec

r = Radius of liquid metal in mold, cm

R = Radius of mold channel, cm

T = Temperature of liquid metal, C

T_i = Initial or pouring temperature, C

T_m = Melting temperature or liquidus temperature, C

T_r = Room temperature (25 C) or initial mold temperature, C

T_{sc} = Temperature of mold at mold-metal interface, C

V = Average metal velocity at any cross-section, cm/sec

V_e = Velocity of end of metal stream, cm/sec

V_i = Initial velocity of metal stream, cm/sec

Z = Height of metal head, cm

d' = Thermal diffusivity of mold, cm^2/sec

θ = Time after metal starts to flow, sec

θ_h = Time after metal-mold contact, sec

θ_f = Final freezing time, sec

ρ = Metal density, gm/cm^3

ρ' = Mold density, gm/cm^3

ϕ_{ent} = Entrance loss coefficient

CAST LOW ALLOY STEELS DUCTILITY AND TOUGHNESS

Reduced phosphorus and sulfur content significance

By John Zotos

ABSTRACT

A developed basic-electric arc furnace melting practice was employed to produce low sulfur and low phosphorus 1040, 4140, high nickel 4325, 4330 and high silicon 4340 type steel castings. The castings produced were chemically analyzed, and the high nickel 4325 and 4330 cast steels were subjected to various heat treatments and physically tested. A decrease in the sulfur content of the high nickel 4325 steel castings resulted in a significant increase in the reduction in area, impact strength and elongation, while mantaining a constant strength level.

A decrease in both the phosphorus and sulfur content of several 4325 and 4330 steel castings also resulted in a significant improvement in their ductility and impact resistance.

INTRODUCTION

The basic-electric steelmaking process permits the refining of steel under oxidizing, neutral and reducing conditions, and with adequate slag control, produces good quality steels.[1,2] In the basic-electric practice, phosphorus is removed during the oxidizing period and sulfur is removed primarily during the reducing period. Furthermore, compared to other steel processes such as the basic-open-hearth, the basic-electric practice can produce cleaner steels of more uniform composition, from poorer raw materials.[3]

Many investigators have studied the reactions occurring between the slag and metal during the production of basic-electric steels.[4-11] Slag characteristics which affect phosphorus and sulfur removal during the basic-electric practice include basicity, oxidizing power and fluidity.[12-14]

The oxidizing period in the basic-electric steel practice commences with the formation of the molten metal. The objectives during this period are to reduce the carbon content of the steel, produce a vigorous boil to intermix the slag and metal and aid in nitrogen and hydrogen removal and oxidize the phosphorus in the steel to calcium phosphate, which is ultimately removed in the deslagging operation. The majority of the elements present in the steel oxidize to varying degrees, and the reactions which occur are discussed in detail in the literature.[1-14]

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The reducing period in the basic-electric steel practice commences with the deoxidation of the molten steel by the controlled addition of deoxidizers such as ferrosilicon, ferromanganese and carbon.[10] The objective during this period is to reduce the sulfur content of the steel by forming a basic reducing slag containing two per cent calcium carbide (CaC_2).[14] The calcium carbide combines chemically with the coke, lime, fluorspar and silicon in the slag, desulfurizes the steel and returns reducible compounds of manganese, chromium, iron, etc., from the slag back into the metal.[7,8] Sulfur removal improves with increased slag basicity and higher bath temperatures.[14]

Other investigators have studied both the effect of deoxidation practice, and the combined effect of phosphorus and sulfur content, melting practice and testing temperature on the physical properties of basic-electric, cast low alloy steels.[15,17] In general, basic-electric steel castings with decreased phosphorus and sulfur contents have the best ductility and impact resistance.[17]

In reviewing the published data, insufficient information was available on the physical properties of cast low alloy steels having phosphorus and sulfur contents in the vicinity of 0.010 per cent. This report presents the results of investigations conducted to evaluate the significance of reduced phosphorus and sulfur contents on the ductility and toughness of cast low alloy steels.

PROCEDURE

The effect of decreased phosphorus and sulfur content on the mechanical properties of low alloy steel castings was studied during the development of an operating procedure for producing low phosphorus and low sulfur steel in a 9 ft diameter, basic-electric arc melting furnace. This melting practice (described in Appendix A) initially produced 4140 and high nickel 4325 steel castings with average sulfur and phosphorus contents of 0.010 per cent, and was later used to evaluate its effectiveness in producing 1040, 4330 and high silicon 4340 type cast steels.

The 1040, 4140 and high silicon 4340 steels were cast into 6 and 8 in. diameter coupons (25 in. long) which were processed and chemically tested.

The high nickel 4325 steel was cast into 90mm (M-41) breech rings and 4 in. test coupons which were shaken out, chemically analyzed and subjected to the following heat treatment:

Normalized at 1900 F, 16 hr and air cooled.

Austenitized at 1650 F, 6 hr; furnace cooled to 1500 F, 2 hr; water quenched, 6 min; air cooled for 10 min; oil quenched 15 min.

Tempered at 600 F, 2 hr; raised to 1130 F, 6 hr; oil quenched for 15 min.

Soaked at 600 F, 12 hr and air cooled.

The 4330 steel was cast into 280mm shell bodies and 4 in. test coupons which were shaken-out, chemically analyzed and subjected to the following heat treatment:

Normalized at 1900 F, 16 hr and air cooled.

Austenitized at 1625 F, 5 hr; furnace cooled to 1500 F, 1½ hr; water quenched, 5 min; air cooled, 5 min; oil quenched, 10 min.

Tempered at 1000 F, 5 hr and water quenched.

Soaked at 600 F, 12 hr and air cooled.

Upon completion of the heat treatment the breech rings, shell bodies and coupons were physically tested in accordance with Military Specification, MIL-S-10029. The 0.357 in. diameter, 3¼ in. long, shoulder-type tensile specimens[19] were removed from specified locations in the castings[18] and tested at room temperature to determine their tensile strength, yield strength at 0.1 per cent offset, per cent elongation and per cent reduction in area. The 0.394 in. square, 2.165 in. long, V-notch Charpy specimens[19] were also obtained from specified locations in the castings[18] and tested at −20 F (−29 C) to determine their impact strength.

RESULTS AND DISCUSSIONS

The chemical analyses of the 14 steel heats produced during this investigation are listed in Table 1.

Figure 1 illustrates the relationship between the sulfur content of the steel and the processing time. Based on the average curve, the meltdown sulfur content of the steels produced is 0.024 per cent and the final sulfur content is 0.008 per cent, indicating that 67 per cent of the sulfur originally contained in the scrap charge was removed using the developed melting practice. Breaking the results down into the various periods of the procedure, the average curve shows that 0.002 per cent sulfur was removed from the steel during the oxidizing period and an additional 0.002 per cent sulfur was eliminated during the wash period.

Thus, the first two periods account for only 25 per cent of the total sulfur removed. During the reducing period, the average sulfur curve drops 0.012 per cent (Fig. 1), indicating that the reducing slag used during this investigation removed 75 per cent of the total sulfur eliminated over the entire heat cycle.

Similarly, Fig. 2 illustrates the variation in the phosphorus content of the steels with increasing process time. Based on the average curve, 0.018 per cent phosphorus was removed from the steel during the oxidizing period, and a constant phosphorus level was main-

TABLE 1 — ANALYSES OF HIGH QUALITY STEELS PRODUCED USING DEVELOPED OPERATING PROCEDURE IN SIX AND ONE-HALF TON BASIC ELECTRIC FURNACE

Heat No.	Type of Steel	STEEL COMPOSITION IN PER CENT							
		C	Mn	Si	Cr	Mo	Ni	S	P
1	1040	0.40	0.92	0.21	—	—	—	0.014	0.013
2	4140	0.43	0.80	0.19	1.07	0.25	—	0.013	0.012
3	4140	0.39	1.33	0.37	1.08	0.21	—	0.009	0.011
4	4140	0.41	0.99	0.35	1.05	0.19	0.42	0.012	0.010
5	HiNi 4325	0.26	1.50	0.45	0.92	0.45	2.45	0.010	0.012
6	HiNi 4325	0.29	1.23	0.32	0.75	0.45	2.50	0.007	0.010
7	4330	0.29	0.96	0.23	0.98	0.37	2.04	0.005	0.007
8	4330	0.31	0.94	0.20	0.88	0.36	2.02	0.012	0.011
9	4330	0.32	1.19	0.46	0.83	0.36	2.02	0.007	0.006
10	4330	0.285	1.59	0.44	1.00	0.40	2.02	0.010	0.021
11	4330	0.26	0.85	0.35	0.88	0.34	1.92	0.011	0.019
12	4330	0.30	1.12	0.45	0.89	0.36	2.07	0.009	0.010
13	4330	0.305	1.22	0.23	0.97	0.33	1.96	0.009	0.010
14	HiSi 4340	0.42	0.82	3.20	1.06	0.29	1.92	0.010	0.011

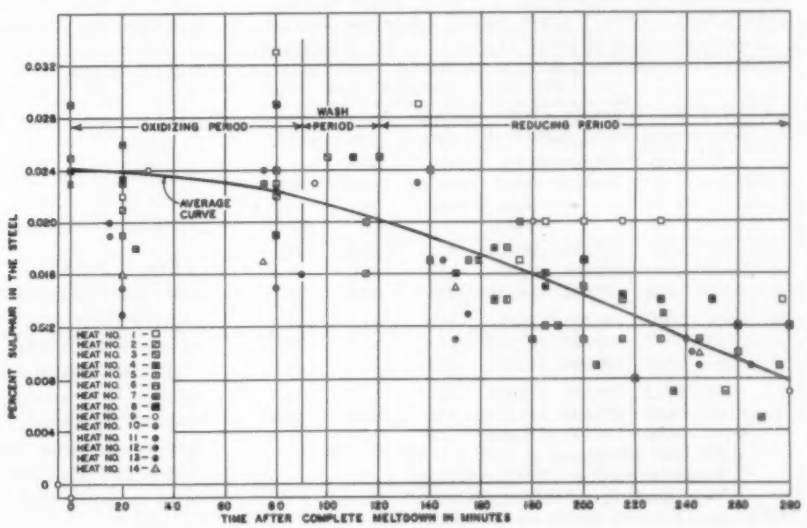

Fig. 1 — Relationship between the sulfur content of the steels and the processing time.

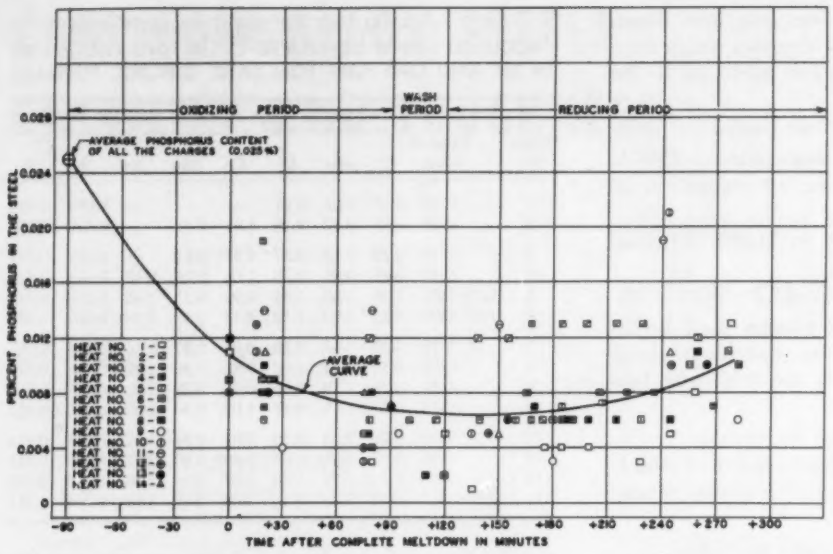
OXIDIZING PERIOD
WASH PERIOD
REDUCING PERIOD
AVERAGE PHOSPHORUS CONTENT OF ALL THE CHARGES (0.025 %)
AVERAGE CURVE
PERCENT PHOSPHORUS IN THE STEEL
TIME AFTER COMPLETE MELTDOWN IN MINUTES

Fig. 2 — Relationship between the phosphorus content of the steels and the processing time.

tained during the wash period. During the reducing period, the average phosphorus curve rose 0.004 per cent to a final value of 0.010 per cent. This rise in phosphorus content can be accounted for as being present in the alloy additions to the steel during the refining period.

These results indicate that the oxidizing slag used during this investigation, removes the bulk of the phosphorus contained in the initial scrap steel charge.

A series of nine basic-electric, high nickel 4325 breech ring steel coupons having a constant low phosphorus content (0.010 ± 0.002 per cent) and varying sulfur content (0.007 to 0.037 per cent) were subjected to the uniform heat treatment previously described and then physically tested. The results, listed in Table 2, indicate that the tensile and yield strength levels remained relatively constant (133,000 ± 8000 psi and 118,000 ± 6000 psi, respectively) while the ductility and toughness improved with decreasing sulfur content.

TABLE 2 — PHOSPHORUS AND SULFUR CONTENT AND PHYSICAL PROPERTIES OF NINE HIGH NICKEL 4325 BASIC-ELECTRIC STEEL HEATS OBTAINED FROM A STANDARD BREECH RING COUPON (4 IN. DIAMETER)

Heat No.	HiNi 4325 Steel Analysis		PHYSICAL PROPERTIES* Tensile Strength (Rm. Temp)	Yield Strength, 0.1% Offset (Rm. Temp.	Elongation (Rm. Temp), %	Reduction (Rm. Temp), %	V-Notch Charpy Impact, −29 F or −29 C (Ft lb)
	S, %	P, %					
A	0.037	0.010	142,250	126,500	12.8	22.4	14.2
B	0.032	0.009	133,000	120,000	13.3	26.8	18.4
C	0.0275	0.010	133,000	118,750	13.6	26.3	23.5
D	0.024	0.008	132,000	118,250	15.4	23.5	34.2
E	0.017	0.012	130,500	117,500	17.1	42.8	35.6
F	0.014	0.009	126,000	112,000	17.9	44.9	36.5
G	0.010	0.012	132,375	116,250	18.6	51.0	34.1
H	0.008	0.009	135,600	120,250	18.6	49.6	38.6
I	0.007	0.010	130,500	115,000	18.6	46.3	38.8

Per cent phosphorus = 0.010 ± 0.002.
Tensile strength = 133,000 ± 8000 psi.
Yield Strength = 118,000 ± 6000 psi.

*All Physical property results are an average of two tests.

Sulfur Content Effect

Figure 3 illustrates this effect of sulfur content on the reduction in area, elongation and impact strength of the high nickel 4325 steel castings. A linear regression analysis (Appendices B, C and D) of the data resulted in the following mathematical relationships:

1) (% R. A) = −975 (%S) + 57.3.
2) (Impact) = −782 (%S) + 45.7.
3) (% Elong) = −215 (%S) + 20.4.

where:

% R.A. = Room temp. per cent reduction in area.
Impact = Charpy V-notch impact strength in ft-lb at −20 F or 29 C.
% Elong. = Room temp. per cent elongation.
%S = the per cent sulfur contained in the steel.

The correlation coefficients resulting from the statistical analyses (Appendices B, C and D) were −0.971, −0.927 and −0.983 for equations (1), (2) and (3), respectively. Using these equations, it is evident that a reduction in sulfur content from 0.030 to 0.010 per cent increases:

1) The reduction in area 70 per cent (from 28.0 to 47.6).
2) The impact resistance 70.7 per cent (from 22.2 to 37.9).
3) The elongation 30 per cent (from 14 to 18.2).

Thus, a reduction in the sulfur content of basic-electric, high-nickel 4325 cast steel significantly improves the ductility and toughness while maintaining a constant strength level.

Extrapolating the per cent sulfur in the high nickel 4325 steel castings (Fig. 3) to zero, and comparing the resulting physical properties to a 0.030 per cent sulfur steel, a maximum increase of 104.6, 105.8 and 45.7 per cent in the reduction in area, impact strength and elongation, respectively, can be predicted.

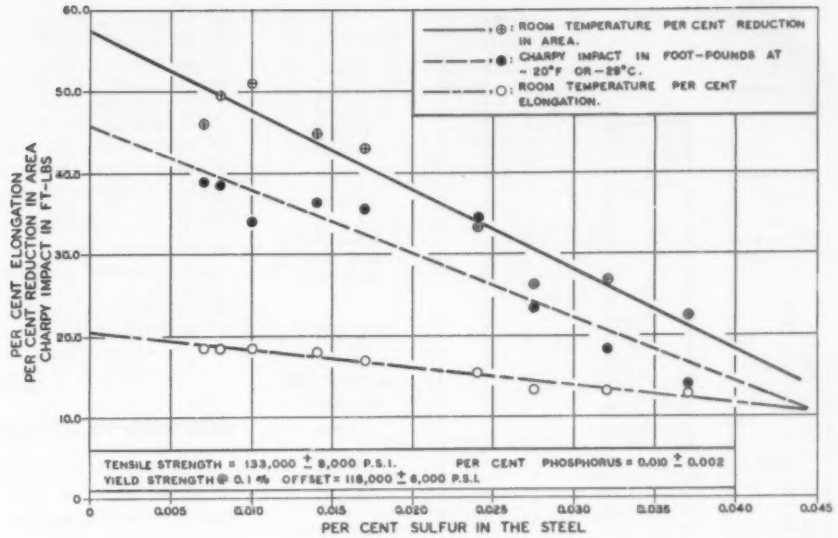

Fig. 3 — Sulfur content effect on the physical properties of cast high nickel 4325 steels.

Several 4325 and 4330 steel castings produced by both basic-electric and basic-induction melting practices and having low and moderate phosphorus and sulfur contents, respectively, were subjected to the heat treatments previously described and then physically tested. The results listed in Table 3 are graphically illustrated in Fig. 4. At relatively constant strength levels (132,000 psi), the 0.008 per cent phosphorus and 0.009 per cent sulfur 4325 basic-electric steel castings have reduction in area, impact and elongation properties which are 16.8, 7.2 and 12.9 per cent greater, respectively, as compared to the 4325 basic-induction steel castings having 0.016 per cent phosphorus and 0.018 per cent sulfur.

In addition, at constant strength levels (156,000 psi), the 0.010 per cent phosphorus and 0.009 per cent sulfur 4330 basic-electric steel castings have reduction in area, impact and elongation properties which are 21.8, 116.7 and 12.4 per cent greater, respectively, as compared to the 4330 basic-induction steel castings having 0.012 per cent phosphorus and 0.025 per cent sulfur. Data available in the literature on a 4330 steel casting subjected to a similar heat treatment (T.S. – 150,000 psi) and containing 0.013 per cent phosphorus and 0.015 per cent sulfur had an impact strength of 15 ft lb at –20 F compared to the low phosphorus and sulfur 4330 steel value of 36.4 ft lb.

These results indicate that reduced phosphorus and sulfur content significantly improves the ductility and impact resistance of 4325 and 4330 steel castings while the strength levels remain constant.

ACKNOWLEDGMENT

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TABLE 3 — ANALYSES AND PHYSICAL PROPERTIES OF SEVERAL STEEL HEATS

Type of Steel	Melting Practice	STEEL ANALYSIS IN PER CENT								PHYSICAL PROPERTIES				
		C	Mn	Si	Cr	Mo	Ni	S	P	Tensile Strength (Rm. Temp)	Yield Strength, 60.1% Offset (Rm. Temp)	Elongation (Rm. Temp), %	Reduction in Area (Rm. Temp), %	V-Notch Charpy Impact in ft lb (–20 F or –29 C)
HiNi 4325	Basic-Electric	0.245	0.87	0.42	0.74	0.44	2.48	0.008	0.009	132,750	116,000	19.3	52.9	39.4
HiNi 4325	Acid-Induction	0.25	0.79	0.33	0.72	0.45	2.34	0.018	0.016	133,000	117,500	17.1	45.3	36.8
4330	Basic-Electric	0.305	1.22	0.23	0.97	0.33	1.96	0.009	0.010	156,000	141,000	13.6	38.0	36.4
4330	Acid-Induction	0.27	0.80	0.36	0.86	0.35	2.01	0.025	0.013	157,500	145,000	12.1	31.2	16.8
4330*	Basic-Electric	0.32	0.76	0.40	0.69	0.32	1.65	0.015	0.013	150,000	——	—	—	15.0

*Data were obtained from reference 17 and the heat treatment used was:
Normalized at 1650 F, 8 hr and air cooled.
Austenitized at 1600 F, 6 hr and oil quenched.
Tempered at 1020 F, 1 hr and water quenched.

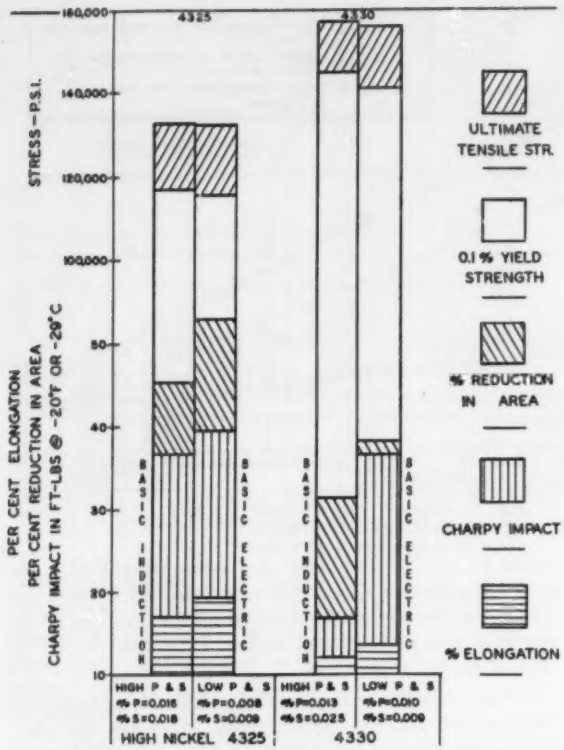

Fig. 4 — Phosphorus and sulfur effect on the physical properties of cast 4325 and 4330 steels.

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APPENDIX A

MELTING PRACTICE

The operating procedure established for producing 14 heats of high quality, low sulfur and phosphorus cast steel was as follows:

1) The charge consisted of 12,000 lb of scrap, 400 (amount of coke varied according to per cent lb of limestone and 50 lb of calcined coke carbon in the scrap; a meltdown carbon of approximately 0.8 per cent was desired). The limestone and coke were loaded into the furnace after the bottom was lined with a thin layer of scrap and the remaining scrap was added.
2) Meltdown of the charge was initiated.
3) A 20-min waiting period followed the meltdown during which the bath was rabbled several times with the aid of a steel skimmer, and a bath temperature of 2850 F to 2950 F was maintained.
4) Metal test specimen *A* was taken and analyzed for carbon, manganese, silicon, chromium, molybdenum, nickel, sulfur and phosphorus.
5) Oxidation commenced with a controlled addition of 480 lb of dry iron ore and 200 lb of limestone, premixed together and added over a 45 min period.
6) One hr after the start of the ore addition, the slag (meltdown slag plus oxidizing slag) was removed through the slag door with the aid of steel skimmers. During this period, the phosphorus in the steel oxidized and reacted with the slag to produce calcium phosphate, which was removed during the deslagging operation.
7) After the first slag-off, metal test specimen *B* was taken for carbon, sulfur and phosphorus analyses.
8) The wash slag consisting of 180 lb of limestone and 42 lb of dry fluorspar was added to the clean steel bath. This slag absorbed any excess phosphates remaining after the oxidizing slag had been removed, and minimized the possibility of phosphorus reverting back into the molten steel.
9) Thirty min later the wash slag was removed. The steel bath was rabbled several times during the wash period to intermix the slag and metal.
10) After the second slag-off, the reducing slag was added in the following sequence:
    a) 90 lb of ferrosilicon, 60 lb of ferromanganese and 10 lb of carborite were added.

b) Upon complete solution of the components added in *a*, the premixed slag consisting of 360 lb of limestone, 60 lb of dry fluorspar and 15 lb of fine ferrosilicon was added.

c) When this slag became molten, powdered coke amounting to 30 lb in total was added to the slag at various intervals and intermixed with the slag by rabbling the bath. This aided in the formation of calcium carbide for favorable desulfurization.

d) Varying amounts of limestone, fluorspar, ferrosilicon and coke were added at intervals to properly shape up the slag. The bath was rabbled several times and the bath temperature was maintained between 2900 F and 2950 F.

During this period, the sulfur in the steel reacted with the slag to produce calcium sulfide, which remained in the slag if a high basicity was maintained.

11) After the reducing slag had shaped up, metal test specimen *C* was taken for a complete analysis (step 4).

12) Upon receipt of the analysis of metal test specimen *C*, the appropriate nickel, chromium, molybdenum and carbon additions were made in the form of ferro-alloys.

13) Upon complete solution of these alloy additions, the power input was raised to bring the bath up to the desired pouring temperature.

14) Ferro-alloy additions of manganese and silicon, based on metal test *C* were made and the molten steel was heated to the tapping temperature.

15) The final metal test specimen *D* was taken for a complete analysis and the heat was tapped into the bottom pour ladle.

16) One-tenth of 1 per cent aluminum was added to the ladle during the tapping operation to assure maximum deoxidation.

17) The various steels produced were cast into 6 and 8 in. billets (1045, 4140, and high silicon 4340), 90mm breech rings and test coupons (high nickel 4325) and 280mm shell bodies and test coupons (4330).

18) The castings were processed and evaluated for their chemical and physical properties.

APPENDIX B

LINEAR REGRESSION ANALYSIS OF THE VARIATION IN THE ROOM TEMPERATURE PER CENT REDUCTION IN AREA WITH DECREASING SULFUR CONTENT IN HIGH NICKEL 4325 STEELS

Y = Rm. temp. per cent reduction in area (Table 2)

$$\bar{Y} = \frac{\Sigma Y}{N} = \frac{343.6}{9} = 38.2$$

X = Per cent sulfur (Table 2)

$$\bar{X} = \frac{\Sigma X}{N} = \frac{0.1765}{9} = 0.0196$$

Summation Results:

1) $N = 9$
2) $\Sigma (X - \bar{X}) = +0.0001$
3) $\Sigma (Y - \bar{Y}) = 0.2$
4) $\Sigma (X - \bar{X})^2 = +0.00096189$
5) $\Sigma (X - \bar{X})(Y - \bar{Y}) = -0.93763$
6) $\Sigma (Y - \bar{Y})^2 = +968.76$

Correlation Coefficient – r:

$$r = \frac{\left(\frac{\Sigma (X-\bar{X})(Y-\bar{Y})}{N}\right) - \left(\frac{\Sigma (X-\bar{X})}{N} \times \frac{\Sigma (Y-\bar{Y})}{N}\right)}{\sigma_X \times \sigma_Y} = -0.971$$

where:

$$\sigma_X = \left[\frac{\Sigma (X-\bar{X})^2}{N} - \frac{\Sigma (X-\bar{X})^2}{N}\right]^{1/2} = \pm 0.01034$$

$$\sigma_Y = \left[\frac{\Sigma (Y-\bar{Y})^2}{N} - \frac{\Sigma (Y-\bar{Y})^2}{N}\right]^{1/2} = \pm 10.38$$

Equation for Best Fitting Straight Line:

$$(Y - \bar{Y}) = \frac{r\sigma_Y}{\sigma_X}(X - \bar{X}) - \frac{r\sigma_Y}{\sigma_X}\left[\frac{\Sigma (X-\bar{X})}{N}\right] + \frac{\Sigma (Y-\bar{Y})}{N}$$

Negligible

$$(Y - 38.2) = -975\,(X - 0.0196)$$
$$Y - 38.2 = -975\,X + 19.1$$
$$Y = -975 \times 57.3$$
$$(\%\ \text{R.A.}) = -975\,(\%S) + 57.3$$

APPENDIX C

LINEAR REGRESSION ANALYSIS OF THE VARIATION IN THE V-NOTCH CHARPY IMPACT (—20 F or —29 C) WITH DECREASING SULFUR CONTENT IN HIGH NICKEL 4325 STEELS

V-Notch Charpy Impact

Y = in ft lb –20 F or –29 C (Table 2)

$$\bar{Y} = \frac{\Sigma Y}{N} = \frac{273.9}{9} = 30.4$$

X = Per cent sulfur (Table 2)

$$\bar{X} = \frac{\Sigma X}{N} = \frac{0.1765}{9} = 0.0196$$

Summation Results:

1) $N = 9$
2) $\Sigma (X - \bar{X}) = +0.0001$
3) $\Sigma (Y - \bar{Y}) = +0.3$
4) $\Sigma (X - \bar{X})^2 = +0.00096189$
5) $\Sigma (X - \bar{X})(Y - \bar{Y}) = -0.75263$
6) $\Sigma (Y - \bar{Y})^2 = +684.23$

Correlation Coefficient – r:

$$r = \frac{\left(\frac{\Sigma (X-\bar{X})(Y-\bar{Y})}{N}\right) - \left(\frac{\Sigma (X-\bar{X})}{N} \times \frac{\Sigma (Y-\bar{Y})}{N}\right)}{\sigma_X \times \sigma_Y} = -0.927$$

where:

$$\sigma_X = \left[\frac{\Sigma (X-\bar{X})^2}{N} - \frac{\Sigma (X-\bar{X})^2}{N}\right]^{1/2} = \pm 0.01034$$

$$\sigma_Y = \left[\frac{\Sigma(Y-\bar{Y})^2}{N} - \frac{\Sigma(Y-\bar{Y})^2}{N}\right]^{1/2} = \pm 8.72$$

Equation for Best Fitting Straight Line:

$$(Y-\bar{Y}) = \frac{r\sigma_Y}{\sigma_X}(X-\bar{X}) - \frac{r\sigma_Y}{\sigma_X}\left[\frac{\Sigma(X-\bar{X})}{N}\right] + \frac{\Sigma(Y-\bar{Y})}{N}$$

Negligible

$$(Y-30.4) = 783\,(X-0.0196)$$
$$Y-30.4 = -782\,X + 15.3$$
$$Y = -782\,X + 45.7$$
$$(\text{Impact in ft-lbs}) = -782\,(\%S) + 45.7$$

APPENDIX D

LINEAR REGRESSION ANALYSIS OF VARIATION IN ROOM TEMPERATURE PER CENT ELONGATION WITH DECREASING SULFUR CONTENT IN HIGH NICKEL 4325 STEELS

Rm. temp. per cent
Y = Elongation (Table 2)

$$\bar{Y} = \frac{\Sigma Y}{N} = \frac{145.9}{9} = 16.2$$

X = Per cent sulfur (Table 2)

$$\bar{X} = \frac{\Sigma X}{N} = \frac{0.1765}{9} = 0.0196$$

Summation Results:

1) $N = 9$
2) $\Sigma(X-\bar{X}) = +0.0001$
3) $\Sigma(Y-\bar{Y}) = +0.1$
4) $\Sigma(X-\bar{X})^2 = +0.00096189$
5) $\Sigma(X-\bar{X})(Y-\bar{Y}) = -0.21216$
6) $\Sigma(Y-\bar{Y})^2 = +48.35$

Correlation Coefficient – r:

$$r = \frac{\left(\frac{\Sigma(X-\bar{X})(Y-\bar{Y})}{N}\right) - \left(\frac{\Sigma(X-\bar{X})}{N} \times \frac{\Sigma(Y-\bar{Y})}{N}\right)}{\sigma_X \times \sigma_Y} = -0.983$$

where:

$$\sigma_X = \left[\frac{\Sigma(X-\bar{X})^2}{N} - \frac{\Sigma(X-\bar{X})^2}{N}\right]^{1/2} = \pm 0.01034$$

$$\sigma_Y = \left[\frac{\Sigma(Y-\bar{Y})^2}{N} - \frac{\Sigma(Y-\bar{Y})^2}{N}\right]^{1/2} = \pm 2.32$$

Equation for Best Fitting Straight Line:

$$(Y-\bar{Y}) = \frac{r\sigma_Y}{\sigma_X}(X-\bar{X}) - \frac{r\sigma_Y}{\sigma_X}\left[\frac{\Sigma(X-\bar{X})}{N}\right] + \frac{\Sigma(Y-\bar{Y})}{N}$$

Negligible

$$(Y-16.2) = -215\,(X-0.0196)$$
$$Y-16.2 = -215\,X + 4.2$$
$$Y = -215\,X + 20.4$$
$$(\%\ \text{Elongation}) = -215\,(\%S) + 20.4$$

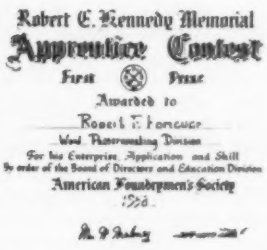
Apprentice Contest Enters Second Month of Competition

■ Competition in the 1960 AFS Robert E. Kennedy Memorial Apprentice Contest is now entering its second month. Competition will end April 8.

Only one rule change has been made in the official contest rules. In the patternmaking competition, AFS tentative standard colors are to be used on pattern entries. The other rules are unchanged.

The contest is based on individual skill and initiative and all work must be certified as that of an individual, completed without advice, help or consultation.

Patterns and blueprints will be supplied to contestants either by the AFS Central Office or the local chapter contest committee. Other equipment and supplies are to be furnished by the contestant or his shop. Contestants are not permitted to examine the pattern or blueprint prior to entering competition and must not be informed as to their nature.


Robert E. Kennedy Memorial
Apprentice Contest
First Prize
Awarded to
Robert T. Forrester
Wood Patternmaking Division
For his Enterprise, Application and Skill
by order of the Board of Directors and Education Division
American Foundrymen's Society
1956

Certificates of recognition are awarded to national winners.

All molding entries must be made in green sand molds only. If baked cores are needed they do not have to be made by the contestant. The first casting poured from the first mold completed will be the only casting eligible for competition.

All castings must be blasted and must not be coated, ground, chipped or welded. Risers and gates must not be removed.

Pattern Entries

Tentative AFS standard colors are to be used on pattern entries. Patternmaking time starts when the contestant personally receives the blueprint and must include all planning and study time. Shellac must be applied but may be still wet when the contestant relinquishes his pattern.

Any apprentice, learner or trainee in the metalcasting industry with not more than five years in patternmaking experience nor more than four years molding experience is eligible. The amount of training has no bearing on eligibility and is not considered in the judging.

Winners in apprentice competition are eligible to compete again if qualifying under eligibility rules but may compete in only one division in any year. AFS membership is not required for either apprentice or employer.

Judging

Judging is conducted on a point-score basis determined by the Apprentice Contest Committee of the AFS Education Division. Judges in the national competition will select the three best entries in each of the five divisions: wood patternmaking, metal patternmaking, iron molding, steel molding and non-ferrous molding.

The scoring system:

Wood Patternmaking	
Accuracy according to drawing	35 points max.
Moldability	35 points max.
Workmanship	30 points max.
Time	10 points max.
TOTAL	100 points max.
Metal Patternmaking	
Accuracy according to drawing	50 points max.
Workmanship	30 points max.
Time	20 points max.
TOTAL	100 points max.
Molding Divisions	
Gates and Risers	20 points max.
Yield	10 points max.
Cleanability	10 points max.
General Appearance	20 points max.
Soundness	25 points max.
Time	15 points max.
TOTAL	100 points max.

Prizes and Awards

Cash prizes of $100 will be awarded to national first place winners in each of the five divisions, second place winners will receive $75 and third place winners $50.

In addition, first place winners in each of the five divisions will receive their round trip expenses paid to the 1960 Convention in Philadelphia. Other expenses shall be assumed by the winner, his company or local chapter. All winners in the national competition will receive certificates of recognition signed by AFS President C. E. Nelson.

AFS 1896

news and views

Missouri Valley

Regional Puts Stress

■ Education and the future of the foundry industry were stressed at the 3d Biennial Missouri Valley Regional Foundry Conference held Sept. 24-25 at the Missouri School of Mines & Metallurgy, Rolla, Mo.

Dean Curtis L. Wilson opened the conference with comments on the recent progress made by the foundry industry. The Dean also credited the engineers with leading the scientists to new fields.

AFS Regional Vice-President Webb L. Kammerer, Midvale Mining & Mfg. Co., St. Louis, told of some of the educational activities of the Society such as MODERN CASTINGS, TRANSACTIONS and the AFS-Training Research Institute program.

AFS General Manager Wm. W. Maloney discussed the Training Research Institute and Society developments. Maloney emphasized, "The primary AFS goal is education of its members." He pointed out that 38 chapters are co-operating in presenting the 11 regional conferences scheduled this year.

Maloney, while talking of progress made in the industry during the past 15 years, observed that even greater advances are possible but warned that foundrymen alone hold the key to the industry's future. They must be willing to accept and utilize the latest technology.

Education was stressed again by Howard A. Williams, Eaton Mfg. Co., Cleveland, who stated that for the most part foundries are doing a poor job of educating their customers and understanding their problems. He recommended that foundries deepen their relationship with their customers, make their organizations and ideas available and work with their customers on basic concepts.

Harry H. Kessler, Sorbo-Mat Process Engineers, St. Louis, spoke at the Thursday luncheon, telling his experiences as a referee and showed movies of the Moore-Marciano heavyweight championship fight.

A. Carl Weber, Laclede Steel Co., St. Louis, addressed the conference on "The Engineer Meets His Foreign Friends". He urged more education and a greater participation in current affairs.

Dan A. Mitchell, Progressive Brass Mfg. Co., Tulsa, Okla., was the conference chairman. Sponsors were the AFS St. Louis, Mo-Kan and Tri-State Chapters; the Missouri School of Mines Student Chapter; and the University of Missouri School of Mines & Metallurgy.

Steel Talks

CAST STEEL—THE LATEST WORD IN ENGINEERING MATERIAL, **Jules Henry,** Missouri Steel Castings Co., Joplin, Mo. Cast steel possesses a wide range of mechanical properties, high strength for a given section, weldability, high modulus of elasticity and machinability. Castings provide further advantages of design freedom, reduced stress concentrations, uniform strength and easily altered designs. Steel is readily available at moderate cost in small or large quantities.

Henry said that it is apparent that some design engineers are not aware of the advantages of the use of cast steel as an engineering material. He called for steel foundrymen to make a concerted effort to correct this lack of education of the customers, and to emphasize that steel is the last word in engineering materials. First because it is steel and has all the attributes of this metal, and secondly, it is a casting and so too has all the advantages of the cast process.

DIELECTRIC CORE BAKING, **Mitchell B. Milonski,** American Steel Foundries, Granite City, Ill. Two 100 kw dielectric ovens have been joined in tandem using split electrodes. Advantages after two years include reduced core rodding; evenly baked cores; reduction of indirect labor, handling costs and core inventories; lowering of incentive standards for coremaking with a straight line flow of operations.

CAN A MARKET BE PRODUCED? **George K. Dreher,** Steel Founders Society of America, Cleveland. The foundry industry is running behind the nation's economy, particularly that of the metalworking industry. "We must abandon the "Have you any castings today? attitude and create an aggressive and competitive sales and market development program."

Dreher cited the example of the foundryman who would not use a cast steel hook in his foundry operations although he was a producer of castings. Using the hook as a symbol, Dreher remarked, "Unless a foundry is confident enough of its products to use them in its own plant, its sales force can't sell castings."

CAN A BENTONITE BE EVALUATED?, **Arthur Zrimsek,** Magnet Cove Barium Corp., Rolling Meadows, Ill. Several tests have been developed for evaluating bentonites. However, they are best appraised on the basis of uniformity. Manufacturers use six control factors in production for providing the desired specifications. Consistent results from the same bentonite is the best test.

EIGHT INTERESTING STORIES OF MATERIAL HANDLING AND MAINTENANCE AT GENERAL STEEL CASTINGS, **Vernon Lich,** General Steel Castings Corp., Granite City, Ill. Examples of handling and maintenance improvements were shown in an effort to overcome rising labor costs in a traditionally high labor cost industry. Mechanization and maintenance were balanced in making improvements and additions.

WHAT IS A CEREAL BINDER?, **C. F. Lourich,** Corn Products Sales Co., Chicago. Moisture retention in sand is facilitated by the use of a cereal binder. Benefits of cereal binders include green compression, green deformation, green shear and overhang together with baked tensile strength while not adding to the hot strength of a sand mix.

Iron Talks

FUNDAMENTALS OF CAST IRON METALLURGY, **William H.**

Speaker **A. C. Weber** calls for better understanding of current events.

Speaker **H. A. Williams** tells foundrymen to educate customers.

.....On Education in Foundry Industry

Moore, Meehanite Metal Corp., New Rochelle, N. Y. Speaker stressed the importance of control and undercooling and the relation between undercooling and correct graphite structure of castings.

SAND PRACTICE IN THE IRON FOUNDRY, **Joseph Schumacher,** Hill & Griffith Co., Cincinnati. Reported on experiments with only moisture varied in a sand mix. Wet sand had 4 per cent moisture; dry sand 2.7 per cent moisture; normal sand, 3.5 per cent moisture. Sand at optimum moisture gave best castings and dimensional characteristics. Dry sand produced dirt and some swelling. Wet sand gave definite swelling and roughness.

GATING & RISERING OF IRON CASTINGS, **Charles Walton,** Gray Iron Founders' Society, Cleveland. Basic principles aid foundrymen in utilizing their experience and allows them to do a more rapid, satisfactory and accurate job of rigging work. A combination of practical know-how and use of published research data will solve most problems.

FUNDAMENTALS OF CUPOLA PRACTICE, **Walter R. Jaeschke,** Whiting Corp., Harvey, Ill. Recommended coke size 1/10 inside diameter of cupola, readily combustible by air and low in sulphur. Scrap should approximate the section size of casting being produced. To avoid bridging, metallics should be reduced to reasonable size and proportional to cupola size.

SHELL CORES FOR IRON CASTINGS, **Earl W. Jahn,** Shell Process, Inc., Chicopee, Mass. The shell core process is increasing in popularity because only two materials are involved—sand and resin. On basis of cost, quality and production, cores are being made that would be impossible by any other methods. Initial high cost is offset by decreased weight of shell core.

Jahn said that it was not uncommon to make hollow cores weighing 50 per cent less than solid cores. The cost of oil sand cores is approximately 1¢ per lb for materials compared to 2¢ per lb for shell cores. However, when a shell core is 50 per cent lighter, the net material cost is the same. This has led to a tremendous increase in the use of shell cores. The size of core made in shell has been limited to date by the size of the equipment available.

COLD SETTING CORES FOR IRON CASTINGS, **Daniel R. Chester,** Archer-Daniels-Midland Co., Cleveland. Process used by 400 foundries is suited for jobbing shop making medium and large castings. Advantages include fast fabrication of extremely large cores, better finish and collapsibility, faster baking and reductions in labor costs, rodding and wiring.

Chester said that the future would probably involve minor changes in lay-out and perhaps more modern equipment developed to use with the process. He forecast that the biggest change will come in the material's use of the process. Extensive research programs are being conducted to produce a non-baking, high tensile, good collapsibility type binder.

Non-Ferrous Talks

MELTING & FLUXING NON-FERROUS METAL, **Harry Ahl,** Malleable Iron Fittings Co., Branford, Conn. Recommended practices: use and charge only clean material of known composition; use clean furnaces; melt as quickly as possible; melt in neutral to slightly oxidizing atmosphere; skim without stirring or excessive agitation; maintain accurate temperature measurements over all melts.

Concluded Ahl, "Good melting practice requires an understanding of the mechanics of the melting plus good supervision and can definitely lead to lower costs."

ALUMINUM CASTINGS – DEFECTS & THEIR CORRECTIONS, **D. L. LaVelle,** American Smelting & Refining Co., South Plainfield, N. J. Listed and explained five causes of internal defects which if controlled would result in quality castings. The defects: Non-metallic inclusions, composed of dross, oxides and flux; porosity, composed of trapped air, gas and shrinkage.

MELTING AND CASTING OF ALUMINUM BRONZES, **J. D. Dick,** Montreal Bronze, Ltd., Montreal, Canada. Alloys call for special melting, molding and casting techniques. In melting initial charge should not include material with large surface area to volume ratio. Molding techniques must allow for high shrinkage characteristics and tendency to drossing. Chills recommended for inducing directional solidification.

PERMANENT MOLDING—STATIC & CENTRIFUGAL, **N. A. Birch,** National Bearing Div., American Brake Shoe Co., St. Louis. Took dim view of static permanent molding due to high mold cost and high quantity requirements. Centrifugal castings, vertical or horizontal, give customers improved quality, enhanced mechanical properties and pressure tightness.

NON-FERROUS CASTINGS—DEFECTS & CORRECTIONS, **Ray Cochran,** R. Lavin & Sons, Chicago. Most important feature in brass or bronze gating is a choke. For proper feeding, risers must be located to take advantage of directional solidification and must remain liquid until entire section has solidified. Determine the one pouring temperature best suited to the alloy.

ALMOST EVERY FOUNDRY CAN HAVE IMPROVED SANDS, **E. E. Woodliff,** Sand Service Engineering Co., Detroit. Foundry profits are best when most economical sand practices are used. Select and use binders which allow for successful sands at reasonable costs through the engineering of individual sands. Studying separate binders simplifies their selection and placement in molding and core blends.

Highly important are the stresses created by expansion resulting from the thermal shock created while the pouring of molds is taking place. Woodlift explained that these are but another function of control handled by selection of the additives of sand mixtures.

Northwest Regional Conference

Puts Emphasis

■ **Improvement of castings through application of fundamental knowledge was the theme stressed at the 10th annual Northwest Regional Foundry Conference held Oct. 2-3 at the Benjamin Franklin Hotel, Seattle.**

The conference was sponsored by the AFS British Columbia, Oregon and Washington Chapters with the Washington Chapter acting as host. General Conference Chairman was W. K. Gibb, Atlas Foundry & Machine Co., Tacoma, Wash. Program Chairman was Harold Wolfer, Puget Sound Naval Shipyard, Bremerton, Wash.

Foundrymen were welcomed to the conference by John A. Cherberg, Washington State Lieutenant Governor. Others addressing foundrymen in general sessions were Frank G. Stinebach, Penton Publishing Co., Cleveland, who spoke on "What About the Future;" Wallace H. Campbell, Campbell Industrial Supply Co., Seattle, the banquet speaker; Prater Hogue, Boeing Airplane Co., Seattle, who told about the first year's operation of the 707 jet liner.

HYDRAULICS FOR THE PRACTICAL FOUNDRYMAN, **Prof. William M. Miller,** University of Wisconsin, Seattle, Wash. Translated the results of theoretical hydraulic investigations into everyday language, explaining how a high velocity jet must be reduced to zero turbulence before entering the ingates of the casting cavity. The pouring basin should be extremely large to allow the dissipation of turbulence with the best results coming from an over and under gating system with gates in the cope and ingates in the drag portion.

PATTERN RIGGING, **Edward Rommen,** Puget Sound Naval Shipyard, Bremerton, Wash. Extremely large castings, as long as 58 ft. and as high as 40 ft. with CO_2 cores weighing up to 9 tons, were made for assault landing craft. Desktop models were made for studying the various problems. The CO_2 process was selected on the basis of the volume and size of the cores and its dimensional stability. "Take apart" patterns were constructed for easy removal from the mold following gassing. Gassing was accomplished with lances through a series of steel net wire sheating spaced at 8-in. intervals and laid into the core mixture.

ARCAIR PROCESS IN CLEANING ROOMS, **M. J. Krumm,** Arcair Co., Bremerton, Wash. Cleaning of rough castings, removal of gates and risers can be speeded by melting the metal with an electric arc and blowing it away by a continuous jet of compressed air directed at the point of the arc. Once the operations have been completed, the surface is clean enough for welding without additional preparation. Advantages of the process include faster removal of metal, lower costs and short training time for personnel.

FUNDAMENTALS OF THE CO_2 PROCESS, **E. A. Lange,** U. S. Naval Research Laboratory, Washington, D. C. Liquid sugars are rated as one of the best additives for improving CO_2 sands since they are hygroscopic and tend to stabilize the water content of the solutions. The mixture is best prepared by adding the silicate, syrup and water to the sand and then mixing for three minutes for high gas strength. With the proper control for applications not requiring the maximum rate of hardening, dilution of CO_2 with air to concentration of 50 per cent or even 20 per cent can be used to increase the efficiency of the process. The dry strength of sand bonded sodium silicate is dependent upon the composition of the sodium silicate and the CO_2 gassing time.

PRODUCTION TECHNIQUES FOR DUCTILE IRON AND PROBLEMS OF THE NEW PRODUCER, **David Matter,** Ohio Ferro-Alloys Corp., Canton, Ohio. More than 200 foundries today are producing ductile iron, chiefly in cupolas or electric furnaces. In either case, ductile iron can not be mixed with other forms of iron in melting or handling. Iron foundries were reminded that strict metallurgical controls are needed particularly with sulphur and phosphorus.

Steel foundries, because of their melting operations and use of a high pig-charge, are in a favorable position for ductile iron production. However, returns such as sprues and gates are not used. To guarantee a constant quality in the metal it should be made from a high pig charge with carefully analyzed scrap exclusive of returns.

HIGH STRENGTH ALUMINUM CASTING ALLOYS, **Alan DeRoss,** Kaiser Aluminum & Chemical Sales, Inc., Chicago. Discussed high purity casting alloys, particularly X357, an aluminum-silicon-magnesium type developing exceptional high tensile and yield strengths with good ductility after heat treating. Established foundry techniques are used in melting, fluxing and pouring. Alloy is designed for applications calling for highly stressed parts where high yield strength is important.

NEW FOUNDRY DEVELOPMENTS, **Fred Wiehl,** Federated Metals Div., American Smelting & Refining Co., Los Angeles. Most developments in the foundry industry are associated with, and following World War II. More was accomplished during this period than in the previous 5000 years. This observation was substantiated with more than

Frank G. Steinebach, Penton Publishing Co., speaking on "What About the Future."

E. A. Lange, Naval Research Laboratory, explains principles of CO_2 operations.

Alan DeRoss, Kaiser Aluminum & Chemical Sales, Inc., outlines new aluminum alloys.

On Fundamentals

20 contributions to foundry technology including developments in melting, degassing, molding, metallurgy, cleaning and heat treating.

WHAT CAN WE DO WITH WEST COAST SANDS?, **Frank Brewster,** Brumley-Donaldson Co., Los Angeles. Only in special cases is it necessary to import sands west of the Rockies for West Coast casting production. Considerable use is made of Nevada washed silicas, particularly for gray iron and steel operations. These sands are similar to New Jersey silicates and are graded in three AFS numbers. The Nevada silicates for shell process require more resin than New Jersey or Ottawa sands. Other West Coast sands are more angular than Nevada sands and contrary to general belief, angular sands do not form as good a bond as do round grained sands.

CORE OIL, **John Bermingham,** E. F. Houghton & Co., San Francisco. New and better core oils are constantly being developed with concentration focused on producing better setting times. In a normal core baking cycle, 75 per cent of the time is needed to drive off moisture with only 25 per cent devoted to setting the binder.

SAND PRACTICES AT ESCO, **A. A. Belusko,** Electric Steel Foundry Co., Portland, Ore. Principal tonnage is produced with Ottawa sands, 48 gfs and 70 gfs. They are chiefly blended for better finish but are also used separately. Two Olivines, 40 gfs and 70 gfs, are blended for use with manganese steels. For shell operations, Nevada sands, 115 gfs, are combined with small amounts of iron oxide in the resins.

WHAT'S NEW IN CORES?, **Richard Grogan,** Archer - Daniels - Midland Co., Los Angeles. Constant improvement is being made in all phases of core-making practices. An evaluation of advantages and limitations of current practices were outlined for conventional core oil practice, CO_2, shell core, resin binders, air-set process and the new chemically cured process. The CO_2 process, said to be used in some extent by 40 per cent of the nation's foundries, was credited with having the greatest single influence on coreroom practice. No single process is the answer to all coreroom problems but considerable progress was forecast not only in current techniques but also in areas still in the experimental stage.

STEEL MELTING, **Lovick Young,** A-1 Steel & Iron Foundry, Vancouver, B. C. Most foundry production problems can be traced to a lack of attention to sound practices. Among areas which need general improvement are the taking of multiple test bar samples for each heat; proper housekeeping; accurate and complete records for cost study and analysis; continual examination of current foundry operations and improvement in the labor-management field.

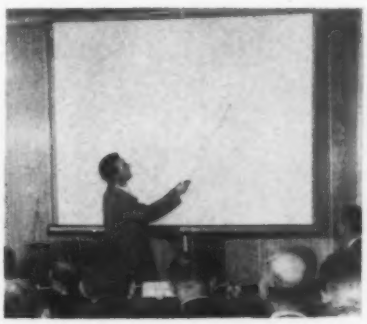
INDUCTION MELTING OF STEEL, **Leroy Fink,** Electric Steel Foundry Co., Portland, Ore. Use of induction melting is increasing for production of both ferrous and non-ferrous metals. Clean foundry scrap is highly essential, either clean foundry scrap or pre-alloyed pig. Scrap should be analyzed and segregated before remelting since removal of sulphur and phosphorus is difficult because of the lack of an open flame or arc for oxidation purposes. The melt should be started with metal of considerable size to obtain the maximum energy from the induced current. Smaller pieces then may be added for rapid melting. Housekeeping of the induction furnace is extremely important and essential with crucibles where special alloy heats are being conducted.

Washington Chapter Chairman, **Vernon W. Rowe,** was toastmaster at luncheon meeting.

Leroy Fink, Electric Steel Foundry Co., tells of increasing growth of induction melting.

Frank Brewster, Brumley-Donaldson Co., tells how western sands are used.

...hard Grogan, Archer-Daniels-Midland Co., ...livering talk on core developments.



University of Washington Professor **W. M. Miller,** explains problems of hydraulics.

Lieut. Governor of Washington, **John A. Cherberg,** welcomes delegates to conference.

AFS **Heat Transfer Committee.** Shown are **R. W. Ruddle,** Foundry Services, Inc.; **R. E. Spear,** Aluminum Co. of America; **J. G. Henzel, Jr.,** General Electric Co.; **Victor Paschkis,** Columbia University; **H. J. Fisher,** General Electric Co.; **W. K. Bock,** National Malleable & Steel Castings Co.; **R. C. Shnay,** Canada Iron Foundries, Ltd.

Sand Division Program & Papers & Shop Course Committee: R. H. Olmstead, Whitehead Bros., Inc., **C. C. Sigerfoos,** Michigan State University; **T. W. Seaton,** American Silica Sand Co.; **Victor M. Rowell,** H. W. Dietert Co.; **H. J. Weber,** Assistant Technical Director; **E. C. Zirzow,** Werner G. Smith, Inc.

Malleable Division Executive Committee: Eric Welander, John Deere Malleable Works; **C. F. Joseph,** Central Foundry Div., GMC; **C. R. Sorensen,** National Malleable & Steel Castings Co., Cicero, Ill.; **F. W. Jacobs,** Texas Foundries, Inc.; **L. R. Jenkins,** Wagner Castings Co.; **J. W. Beckman,** Texas Foundries, Inc.; **W. C. Truckenmiller,** Albion Malleable Iron Co.; **H. W. Heine,** Malleable Founders' Society; **H. J. Weber,** AFS Assistant Technical Director.

Sand Division Grading, Fineness & Distribution Committee: Herb Loele; L. D. Marinelli, Kensington Steel Co.; **J. G. Smillie,** John Deere & Co.; AFS Assistant Technical Director **H. J. Weber; Stewart Wick,** New Jersey Silica Sand Co.; **W. D. Chadwick,** Manley Sand Co.; **N. J. Stickney,** Sand Products Corp.; **R. J. Maddison,** Whitehead Bros. Co.; **E. W. Smith,** Eugene W. Smith Co.; **Franklin Goettman,** Standard Sand Co.; **Walter Mahlig,** W. S. Taylor Co.

Sand Division Executive Committee; G. J. Vingas, Wehr Steel Co.; **J. A. Terpenning,** Archer-Daniels-Midland Co.; **Lawrence Winnings,** Wagner Castings Co.; **G. W. Anselman,** Whirl Air Flow Co.; **E. C. Zirzow,** Werner G. Smith, Inc.; **Nicholas Sheptak,** Dow Chemical Co., **V. M. Rowell,** H. W. Dietert Co.; **T. M. Seaton,** American Silica Sand Co.; **W. D. Chadwick,** Manley Sand Co.; **W. H. Buell,** Aristo Corp.; **L. E. Taylor,** Ottawa Silica Co.; **F. P. Goettman,** Standard Sand Co.; **A. G. Linley,** LFM Div., Rockwell Mfg. Co., Atchison, Kans.; **J. B. Caine,** consultant, Cincinnati.

Die Casting, Permanent Mold Outlines Plans

■ Plans for the 1960 Convention and organization of the division were discussed at the executive committee meeting of the Die Casting & Permanent Mold Division held during September in Chicago.

The division's committee personnel:

Executive Committee—Chairman, F. C. Bennett, E. V. Blackmun, W. N. Brammer, D. L. Colwell, R. C. Cornell, R. P. Dunn, H. E. Eriksen, W. J. Grassby, Nicholas Sheptak.

Program & Papers Committee—Chairman, R. P. Dunn, E. V. Blackmun, M. E. Brooks, C. B. Curtis, P. D. Frost, J. W. Meier, G. V. Shomos, L. W. Wickson.

Research Committee—Chairman, Nicholas Sheptak, Walter Bonsack, A. B. DeRoss, G. H. Found, P. D. Frost, G. F. Hodgson, P. P. Hoffman, W. A. Mader, John McLaren, Alfred Sugar.

Die Casting & Permanent Mold Process Committee—Chairman, R. C. Cornell, A. Y. Bethune, E. V. Blackmun, M. E. Brooks, F. N. Eaton, H. E. Eriksen, T. J. Fladgen, F. W. Kidney, W. J. Klayer, J. D. McGuire, R. G. McMillen, G. T. Piper, William Schwartz, John Vogt.

1960 Hoyt Lecturer

■ One of the highlights of the 64th Castings Congress will be the 1960 Charles Edgar Hoyt Memorial Lecture by W. J. Grede, president, Grede Foundries, Inc. The tentative title of his talk is "Comparative Position of the Foundry—Present and Future."

W. J. Grede

In 1920 Grede negotiated purchase of the Liberty Foundry in Wauwatosa, Wis. The business has expanded until today Grede Foundries has six plants. The Hoyt Lecturer was awarded the AFS McFadden Gold Medal in 1953 for . . . "Outstanding public service bringing credit upon and broad recognition for the entire foundry industry."

He was the first chairman of the AFS Wisconsin Chapter, a leader in the first AFS foundry conference at the University of Wisconsin and past chairman of the AFS Cost Committee. He was also active in the affairs of G.I.F.S. and A.S.T.M. Grede was the first foundryman to serve as president of the National Association of Manufacturers, a past president of the Wisconsin Manufacturers Association and the Employers Association of Milwaukee and in 1945 was appointed to Labor-Management Conference.

East Coast Regional Conference Nov. 20-21 to Feature Simultaneous Division Meetings

■ Simultaneous gray iron, steel and non-ferrous technical sessions will be held at the East Coast Regional Conference, Nov. 20-21 at the Statler Hilton Hotel, New York.

The two-day conference is sponsored by the AFS Metropolitan, Chesapeake and Philadelphia Chapters. James S. Vanick, International Nickel Co., New York, is the general conference chairman.

FRIDAY, NOV. 20

Morning Sessions

10:00 am GRAY IRON—Gating and Risering.
Solidification and Risering of Gray Iron, Clyde M. Adams, Jr., Massachusetts Institute of Technology, Cambridge, Mass.

10:00 am STEEL—Gating and Risering.
Effect of Soundness on the Mechanical Properties of Cast High-Strength Steel, Hugo Larson, American Brake Shoe Co.

10:00 am NON-FERROUS
Gating and Risering of Bronze Castings, Norman A. Birch, National Bearing Div., American Brake Shoe Co., St. Louis.

11:00 am GRAY IRON—Gating and Risering.
Gating and Risering of Ductile Iron, C. W. Gilchrist, Cooper-Bessemer Corp., Mt. Vernon, Ohio.

11:00 am STEEL—Gating and Risering.
Application of Insulators and Exothermic Compounds to the Risering of Steel Castings, Harold Bishop, Exomet, Inc., Conneaut, Ohio.

11:00 am NON-FERROUS
Recent Developments in Magnesium Foundry Practice, H. E. Elliott, Bay City Div., Dow Chemical Co., Bay City, Mich.

Afternoon Sessions

2:00 pm GRAY IRON—Sand Session.
Gray Iron Molding Sand, Victor Rowell, Harry W. Dietert Co., Detroit.

2:00 pm STEEL—Sand Practice.
Requirements for Steel Molding Sands, Burt Troy, Pennsylvania Electric Steel Castings Co., Hamburg, Pa.

2:00 pm NON-FERROUS
Fundamentals of the CO_2 Molding Process, Eugene A. Lange, Naval Research Laboratory, Washington, D. C.

3:00 pm GRAY IRON—Sand Session.
Veining and Penetration, George DiSylvestro, American Colloid Co., Skokie, Ill.

3:00 pm STEEL—Sand Practice.
Moldability of Steel Sands, George Watson, American Brake Shoe Co., Mahway, N. J.

3:00 pm NON-FERROUS
Quality Control by Non-Destructive Testing of Non-Ferrous Castings, John W. Clarke, Erie Foundry, General Electric Co., Erie, Pa.

SATURDAY, NOV. 21

Morning Sessions

9:30 am GRAY IRON—Melting Session.
Basic Cupola Operation, W. W. Kerlin, Meehanite Metal Corp., New Rochelle, N. Y.

9:30 am STEEL—Melting Session.
Carbon Additives in the Arc Furnace, Stanley Gilbert, Godfrey L. Cabot Co., Boston.

9:30 am NON-FERROUS
Developments in Aluminum Alloys and Casting Practices, E. V. Blackmun, Aluminum Co. of America, Pittsburgh, Pa.

10:30 am GRAY IRON—Melting Session.
Production of Ductile Iron, Ralph A. Clark, Union Carbide Metals Co., Div., Union Carbide Corp., Cleveland.

10:30 am STEEL—Melting Session.
Recent Advances in Steel Melting Practices, John Zotos, Watertown Arsenal, Watertown, Mass.

10:30 am NON-FERROUS
Melting Practice for Bronze Alloys, speaker to be announced.

Wilder Presents Exchange Paper

■ Howard H. Wilder, Vanadium Corp. of America, presented the official AFS Exchange Paper Oct. 7 at the 26th International Foundry Congress held Oct. 4-11 in Madrid, Spain.

Wilder's paper, *Ferroalloys and Inoculants for the Production of High Strength Cast Iron,* illustrated how American foundries achieve a variety of tensile strengths from one basic iron through the use of ferroalloys and inoculants.

Wisconsin Regional Conference Feb. 11-12

■ Wisconsin foundrymen will hold the 23d Wisconsin Regional Foundry Conference Feb. 11-12 at the Hotel Schroeder, Milwaukee, Wis. Sponsors of the regional are the AFS Wisconsin Chapter and the University of Wisconsin.

Bradley Booth, Carpenter Bros., Inc., Milwaukee, is the conference chairman and P. C. Rosenthal, Prof., Dept. of Mining & Metallurgy, University of Wisconsin, Madison, Wis., is conference co-chairman.

J. R. Stockwell Heads Southeastern Regional

■ J. R. Stockwell, Stockham Valve & Fittings, Inc., Birmingham, Ala., is chairman of the Southeastern Regional Conference to be held Feb. 18-19 at the Thomas Jefferson Hotel, Birmingham, Ala.

Charles E. Seaman, Crane Co., Chattanooga, Tenn., is co-chairman and Ernest Finch, American Cast Iron Pipe Co. is program chairman.

The conference is sponsored by the AFS Birmingham and Tennesee Chapters and the University of Alabama Student Chapter.

Members of the AFS **Die Casting & Permanent Mold Executive Committee** met during September in Chicago to discuss organization and the 1960 Convention program. Left to right are: Division Chairman **F. C. Bennett,** Dow Chemical Co., Midland, Mich.; **G. V. Shomos,** Howard Foundry Co., Chicago; **R. C. Cornell,** Litemetal Dicast, Inc., Jackson, Mich.; **W. N. Brammer,** Apex Smelting Co., Cleveland; **D. L. Colwell,** Apex Smelting Co., Cleveland; **W. J. Gressby,** Die Cast Mfg. Div., Bendix Aviation Corp., South Bend, Ind.; **Nicholas Sheptak,** Dow Chemical Co., Midland, Mich.; **R. P. Dunn,** Lindberg Melting Furnace Div., Lindberg Engineering Co., Chicago; **H. J. Weber,** AFS Assistant Technical Director.

Urge Exhibitors to Apply Early for Foundry Show

■ Space assignments are being made for the AFS 1960 Foundry Show to be held May 9-13 at the Philadelphia Trade & Convention Center.

W. N. Davis, AFS Exhibit Manager, states that applications for space are running ahead of the 1958 Foundry show in Cleveland and cautions exhibitors to complete and return application forms early.

Philadelphia has been a key city in AFS Conventions and exhibits. It was host to the first convention in 1896 and in 1948 drew the largest attendance of any Foundry Show east of Cleveland.

A heavy turnout is expected for the 1960 Show. Casting production is up in all lines. September MODERN CASTING: listed a comparison of castings shipments of April, 1958 with April, 1959. These figures show:

Gray iron casting shipments up 160 per cent.

Malleable iron casting shipments up 180 per cent.

Steel casting shipments up 140 per cent.

Aluminum casting shipments up 160 per cent.

Copper casting shipments up 140 per cent.

Zinc casting shipments up 160 per cent.

Magnesium casting shipments up 110 per cent.

As in the past, increased production is reflected in heavier purchases of equipment for replacement and expansion purposes. The latest in equipment and processes for increasing casting quality and production will be featured at the Show. Operating exhibits will be scattered throughout the halls to promote a steady flow of traffic.

Exhibit Manager Davis has these suggestions for exhibitors as an aid to secure their desired locations and to facilitate processing of applications.

- Submit four space choices in at least two of the three halls.
- Make choices in separate and not in adjoining blocks or corners.
- Applications of those with operating exhibits should indicate the expected power and special requirements.

As an aid to exhibitors, AFS will give advance publicity on new products, special demonstrations and product improvements. Exhibitors are requested to describe these in forms provided by AFS.

Castings Congress

The Foundry Show will be presented in conjunction with the 64th AFS Castings Congress. Technical papers on the latest in foundry research and investigations will be sponsored by the Technical Divisions and General Interest Committees. Sessions will be held on each of the five days in the Trade & Convention Center.

Society activities will include the Annual Business Meeting, Hoyt Lecture, Annual Banquet and presentation of Apprentice awards, Awards of Scientific Merit and Service Citations.

Chapter

B. R. Artz
Pangborn Corp.
Syracuse, N.Y.
Chairman
Central New York Chapter

R. E. Heikes
Dempster Mill Mfg. Co.
Beatrice, Neb.
Chairman
Cornbelt Chapter

C. E. Seman
Crane Co.
Chattanooga, Tenn.
Chairman
Tennessee Chapter

Yugoslavian quality castings study team on six-week tour of the United States, under auspices of the International Cooperative Administration, visited AFS Headquarters, Des Plaines, Ill. in September. Shown clockwise from lower right-hand corner are: **Myron R. Brock,** International Cooperation Administration, **Nikola Franki, Ranko M. Sotra,** interpreter **Vlado Stergar,** AFS Secretary **A. B. Sinnott,** AFS General Manager **Wm. W. Maloney,** interpreter **Bogdan Bauer, Franc Seliskar, Radenko M. Petrovic, Franja F. Voler.**

Chairmen-1959-60

R. G. Whitehead
Dace Industries, Ltd.
Windsor, Ont.
Chairman
Detroit Chapter

E. A. Zeeb
Dodge Steel Co.
Philadelphia
Chairman
Philadelphia Chapter

C. G. Mattson
Dependable Pattern Works
Portland, Ore.
Chairman
Oregon Chapter

R. J. Bossong
American Steel Foundries
Alliance, Ohio
Chairman
Canton Chapter

J. C. Mulholland
Pettibone Mulliken Corp.
Chicago
Chairman
Chicago Chapter

A. H. Hinton
Aluminum Co. of America
Cleveland
Chairman
Northeastern Ohio Chapter

R. B. Fischer
Ingersoll-Rand Co.
Phillipsburg, N.J.
Chairman
Metropolitan Chapter

W. E. Boswell
Glamorgan Pipe & Foundry Co.
Lynchburg, Va.
Chairman
Piedmont Chapter

T. Tafel
American-Standard Products (Canada) Ltd.
Toronto, Ont.
Chairman
Ontario Chapter

J. R. Cardwell
Stockham Valves & Fittings Inc.
Birmingham, Ala.
Chairman
Birmingham Chapter

R. E. Hard
St. Louis Coke & Foundry Supply Co.
St. Louis
Chairman
St. Louis Chapter

C. D. Loomis
General Railway Signal Co.
Rochester, N.Y.
Chairman
Rochester, N.Y.

Advanced Courses Conclude AFS-T&RI '59 Program

■ Three courses remain in the 1959 AFS-T&RI schedule which has included presentations in Birmingham, Ala., Chicago, Los Angeles, San Francisco and Ontario, Canada.

These are: *Permanent Mold & Die Casting*, Nov. 9-11, Chicago; *Sand Control Technology*, Nov. 30-Dec. 4, Chicago; *Advanced Industrial Engineering*, Dec. 7-11, Milwaukee.

Permanent Mold, Die Casting

This new course is being presented in answer to numerous requests for basic fundamentals and the newest technology. Subjects to be covered are:

PERMANENT MOLD PROCESS—Advantages and disadvantages, selection of mold material, alloys, molding equipment and operation, mold design and finishing, melting equipment and practice.

DIE CASTING PROCESS—Methods of production, product application, alloys, melting practice, equipment, die design and die life.

VACUUM DIE CASTING—Application and progress, processes, typical uses and advantages and limitations.

PERMANENT MOLD, GRAY IRON—Processes, patterns, mold casting, cavity layout and machining, venting and mold treating.

1959 T&RI-AFS Courses

Nov.-Dec.

Subject and Description — *Dates*

Permanent Mold & Die Casting.....Nov. 9-11
Both theory and practice are emphasized in course for foundrymen interested in the latest developments in their growing fields. Molding materials, gating and risering, new alloys, methods, equipment and product application. Course PMDIA, $60, Chicago.

Sand Control & Technology.....Nov. 30-Dec. 4
Instruction course for foundrymen having had some experience in sand testing, control and technology. Mold wall movement, hot deformation, creep deformation, mold atmosphere, heat transfer, mechanical properties and metal penetration are included. Students bring case problems to class for discussion and solution. Prerequisite: course S1A (Sand Testing) or equivalent experience. Course S2A, $90, Chicago.

Industrial Engineering.....Dec. 7-11
Instruction and workshop course for personnel experienced with basic industrial engineering principles. Practical cost control procedures applied to foundry operations, including work sampling, rating practice and statistical quality control. New techniques in industrial engineering are considered for foundry application. Industrial engineers, cost control personnel, quality control engineers, supervisors and management. Course IE3A, $150, Milwaukee.

Registration

Payment of tuition fees should accompany enrollment applications. Make all reservations only with Director of AFS Training & Research Institute, Golf & Wolf Roads, Des Plaines, Ill. Tel. VAnderbilt 4-0181.

Patternmaking Fundamentals Outlined in AFS-T&RI Course

■ Fundamentals of patternmaking from basic considerations to current and future developments were described in a three-day AFS-T&RI patternmaking course given Sept. 16-18 in Chicago.

Experts in the field donated their time as teachers. Instructors and their subjects were:

Robert LeMaster, R. A. Nelson Co., Milwaukee — wood patterns including lumber, finishing, pattern equipment and identification as well as patternmaking history and present and future areas and plastic materials.

William Cheek, General Motors Corp., Danville, Ill. — production pattern equipment including materials, metals and advantages and disadvantages.

J. N. Mathias, Accurate Match Plate Co., Chicapo — pressure cast metal matchplates and pressure cast metal patterns in plaster.

M. K. Young, U.S. Gypsum Co., Chicago — plaster patterns and gypsum cements, plastic foundry patterns with demonstrations.

Zigmund Madacey, Beardsley & Piper Div., Pettibone Mulliken Corp., Chicago — core blowing including fundamental requirements, equipment types and new developments.

R. L. Olson and **Ed Olson,** Dike-O-Seal, Inc., Chicago — core box design and new horizons in pattern life extension.

Fred Landmann, Brillion Iron Works., Brillion, Wis. — shell mold and shell core pattern equipment consisting of design, pattern materials, making the pattern, stripping pins and core boxes.

AFS-T&RI Training Supervisor R. E. Betterley, conducted an achievement examination and review.

M. K. Young, U. S. Gypsum Co., conducts demonstration for students of AFS-T&RI patternmaking course held during September in Chicago.

AFS-T&RI patternmaking course included lectures, demonstrations and movies demonstrating basic fundamentals and the latest developments.

chapter news

Northeastern Ohio Opens with Joint Sessions

■ Ferrous, non-ferrous and pattern sectional meetings in September opened the 1959-60 program.

Fred C. Barbour, Republic Steel Corp., discussed *New Developments in Cupola Melting* to ferrous foundrymen, describing a procedure for reducing the sulphur content in iron melted in acid-lined cupolas. It includes a hopper or container located close to the cupola and above the tuyeres. Dense soda ash or a combination of soda ash and calcium carbide is fed from the hopper into a tube or pipe projecting horizontally into one of the tuyeres. About 4 lb of soda ash and 4 lb calcium carbide per ton are injected and a considerable reduction of sulphur is obtained. Barbour also described a simple hot blast installation for small cupolas employing a series of vertical tubes connected to circular headers at top and bottom.

Patternmakers attended a panel discussing the patternmaker's responsibility in the design of a casting. Members were Frank J. Gubics, S.O.M. Precision Industries Div., Solon Foundry, Inc.; Jerry M. Hathaway, Massillon Steel Castings Co.; William F. Seelbach, Forest City Foundries. Co. The speakers stressed the need for co-operative efforts among designers, foundrymen and patternmakers and pointed out that the design engineer is receptive to suggestions from patternmakers, particularly in the savings of costs. Specific examples were cited of how economies have resulted through changes in casting design or pattern construction.

At the non-ferrous session, *Horizontal Gating Design* was discussed by Walter E. Sicha, Aluminum Co. of America and Jack J. Kroecker, Permold Co. An AFS film, made at Battelle Memorial Institute, demonstrated the movement of water in lucite molds to parallel the action of molten metal in sand molds. Points stressed by the film and speakers included: keeping pouring rate low; not pouring directly down the sprue; keeping the pouring basin full; using a tapered sprue; avoiding direct changes in metal flow; keeping the runner to gate ratio at 1:4:4. It was further noted that the edge of the pouring box should not be up to the edge of the sprue. Round edges on the pouring box prevent pulling in of air, and a well area at the bottom of the sprue is important to avoid turbulence and sucking in of air.

—W. G. Gude, Edwin Bremer and J. C. Miska

Northeastern Ohio's September meeting opened with ferrous, non-ferrous and pattern sessions. **W. E. Mahoney,** Madison Foundry Co. (left) was chairman of the ferrous session. **F. C. Barbour,** Republic Steel Corp. was the speaker.

Non-ferrous panelists discussing horizontal gating at **Northeastern Ohio's** September meeting shown are **Walter Sicha,** Aluminum Co. of America and **Jack Kroecker,** Permold Co., shown on Right. **Peter J. Peto, Jr.,** Arrow Aluminum Casting Co. was technical chairman.

Panelists included **D. C. Hartman, F. J. Gubics, Wm. F. Seelbach** and **J. M. Hathaway.**
—Harold Wheeler

Central Ohio Chapter

Improving Cupola Operation

■ Windbox construction and tuyere design, charging bucket design for maximum distribution, provisions for quality control in mechanical charging and allowance of adequate working room were stressed by Dan Krause, Gray Iron Research Institute at the September meeting.

D. J. Krause

Instrumentation was discussed for: temperature of metal, physical properties of metal, blast flow and pressure recording, blast humidity control and charge height indicators. Several slides were shown of actual cupola installations demonstrating the latest in design and installation. *—Joe Riley*

Wisconsin Chapter

Conducts Simultaneous Sessions

■ Simultaneous gray iron, steel, nonferrous, malleable and pattern meetings were conducted at the September meeting.

GRAY IRON—J. E. Fitzwater, International Harvester Co., outlined salvage welding and control procedures for multiple and single production items. He discussed salvage welding of gray iron including oxyacetylene, brazing, thermit welding, metallizing, soldering and manual arc welding. The preparation of the casting prior to welding was given emphasis and gouging and chipping to clean the defective area were emphasized. Control was cited as the key to successful salvaging of gray iron castings.

STEEL—A four-man panel discuss *Cleaning Room Incentives*. A. J. Hickey, Sivyer Steel Casting Co., summarized the problems encountered in establishing incentives. Fred Kluessendorf, Crucible Steel Casting Co., spoke on the relative merits of high cycle vs. pneumatic grinding tools and the development of incentives based on handling time, contact time and energy expended. Ray Zobel, Bucyrus-Erie Co., covered welding incentives based on arc time and flame cutting measured by oxygen flow with emphasis on the value of good direct supervision. Orrin V. Cook, Belle City Malleable Co., gave a description of incentives for stand grinding factored from standard data.

G. Leslie Armstrong, U. S. Reduction Co., discussed *Metallurgy of Aluminum Alloys* at the non-ferrous meeting. *—Don Gerlinger*

chapter news

Central New York

Vacuum Induction Melting

■ Two speakers addressed the opening meeting in September, P. W. Nolan and Wolfgan Mategen, Kelsey Hayes Co., New Hartford, New Hartford, N. Y.

W. Mategen

P. W. Nolan

The talks were supplemented by a movie. Chapter Chairman Bruce Artz, Pangborn Corp., Syracuse, N. Y. presided. *—Lewis Balduzzi*

Cincinnati Chapter

Two Speakers Address Chapter

■ Two speakers addressed the opening session held at the Wigwam restaurant.

R. Rathyen

Enos L. Key, Mexico Refractories Co., Div., Kaiser Aluminum & Chemical Sales, Inc., spoke on new developments in foundry refractories. Ralph Rathyen, Joseph Dixon Crucible Co., Jersey City, N.J., spoke on care and use of crucible furnace refractories. Stanley F. Levy, H. P. Deuscher Co., Hamilton, Ohio and Walter H. Kruse, Jr., O.P.W. Corp., Cincinnati, served as technical chairmen. *—Stanley F. Levy*

Northern California Chapter

Supports Apprentice Program

■ Active support of the California apprentice program by the AFS Northern California Chapter and the local molders union has returned dividends for northern California foundries.

During the past 14 years, 350 molding and coremaking apprentices have completed their training with 283 receiving state certificates. More than 90 per cent of these were the result of activity by northern California foundrymen and the union. At present more than 20,000 apprentices are enrolled throughout the state.

The 20th anniversary meeting of the California Apprentice Council, administrators of the Shelley-Maloney Apprentice Labor Standards Act, was held during October in Oakland, Calif., site of the first meeting.

Tri-State Chapter

Aids in Sponsoring Course

■ A 14-week course on sand and sand control is being presented without cost to Tulsa, Okla., area apprentices and foundry personnel.

This is the 19th semester of related training presented jointly by the AFS Tri-State Chapter, Local 325, AFL International Molders and Foundry Workers Union of North America and the Oklahoma State Department of Vocational Education.

The course is presented weekly from Sept. 14 to Dec. 14 at the Tulsa Central High School. R. D. Sullivan, Nemco Foundry Div., Nelson Electric Mfg. Co., Tulsa, is the instructor.

St. Louis Chapter

Presents Books to School

■ A set of AFS books was presented in May by the AFS St. Louis Chapter to John O'Fallon High School, St. Louis. The books were dedicated to the four past chapter officers who died in 1958.

Making the presentation were 1958-59 Chapter Chairman W. C. Pickles, National Bearing Div., American Brake Shoe Co., St. Louis; 1959-60 Chairman Russell E. Hard, St. Louis Coke & Foundry Supply Co., St. Louis and Secretary Paul E. Retzlaff, retired. *—W. E. Fecht*

Ontario Chapter

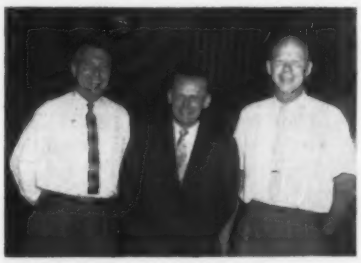
Hears Talk on Sand Properties

■ Sand properties as developed in laboratory tests and used in production were discussed at the September meeting by T. E. Barlow, International Minerals & Chemical Corp., Skokie, Ill. Barlow also spoke of research on the hot properties of sand related to expansion.

—James McCabe

Russell E. Hard, St. Louis Coke & Foundry Supply Co. (left) **St. Louis Chapter Chairman** 1959-60, accepts gavel from retiring chairman **W. C. Pickles,** National Bearing Div., American Brake Shoe Co., St. Louis.
— W. E. Fecht

Francis H. Hohn, Scullin Steel Co., Div. Universal Marion Corp., St. Louis, Congratulates **Leroy E. Taylor,** Ottawa Silica Co., Ottawa, Ill., who addressed the **St. Louis Chapter** in September on "The Production of Foundry Sands. **—W. E. Fecht**



Southern California members in September heard **W. D. Chadwick,** Manley Sand Co., Rockton, Ill., discuss sand segregation in the foundry. He showed a color film demonstrating the behavior of colored dry sand under various conditions of charging and discharging. Left to right are Chapter Treasurer **Bruce Farrow,** Barker Foundry Supply Co., speaker Chadwick and **Paul Crow,** also of Barker Foundry Supply. **—K. F. Sheckler**

Philadelphia foundrymen held their annual **Philadelphia Chapter** picnic in July at the Manufacturers Golf and Country Club, Oreland, Pa. **—E. C. Klank, Leo Houser**

Western New York Holds Annual Picnic

Relaxing are **J. Babiak** and **I. Stohle,** Symington-Wayne Corp.; **Bruce Artz,** Pangborn Corp.; **Al Petz,** Symington-Wayne Corp.; **H. A. Mason, Jr.; Phil Savage,** McCallum Bronze Corp.; **Ron Turner,** Queen City Sand & Supply Co.

Attending **Western New York** picnic were **A. J. Heysel,** E. J. Woodison Co., Buffalo, N.Y. and **L. C. Roberts,** Combined Supply & Equipment Co., Buffalo.

Western New York Chapter held its 22nd annual outing in June. Program consisted of games, prizes and plenty of food.

—**Don Kreuder**

Philadelphia foundrymen beat the suppliers at annual **Philadelphia** picnic after two successive defeats. L. F. Dill and W. J. Gallana headed the entertainment committee.

—**E. C. Klank, Leo Houser**

Birmingham Chapter began its 1959-60 season with its annual picnic, Hassett Lester was the entertainment chairman. Photo shows Chapter Chairman **J. R. Cardwell,** Stockham Valves & Fittings Co. (right) presents TV winner **Ernest Graham.** —**Edwin Phelps**

Central Michigan Chapter

Hears Talk on Iron Ore

■ The 1959-60 program opened in September with a film "Horizons North," showing the step by step development of low grade iron ore into usable high grade ore for blast furnace consumption. E. J. Mapes, Pickands, Mather & Co., also discussed the geological and economic conditions which have made this operation possible. Chapter Chairman Stephen Pasick, Battle Creek Foundry Co., Battle Creek, Mich., presided. —*Melvin Devers*

Quad City Chapter

New Foundry Resins & Uses

■ New foundry resins and application techniques for shell molds and shell cores were explained to 115 members at the September meeting by W. C. Capehart, Monsanto Chemical Co., Springfield, Mass.

Production of satisfactory castings using shell molds and shell cores depends upon an understanding of resins used, most economical resin application technique, ability to analyze a production problem swiftly and a knowledge of proper corrective measures as well as the establishment of suitable controls to insure consistent operations. —*William Ellison*

Ontario Chapter

Conducts Annual Summer Picnic

■ Ontario Chapter members held their annual picnic Sept. 12 at Milton, Ontario. A variety of contests were held. Winners were: golf, L. Cross, C. Gilbert, J. Schlatau; horseshoes, B. Summerhayes, W. Harrington; darts, T. Skelly; balloon tossing, C. Gilbert, C. Fitzherry; waterskiing, J. Wallace, R. Grey, L. Pettinos, H. McLeallum; nail driving, K. Holmes; cornhusking, L. Hisks.

—*Vince Furlong*

Twin City Chapter

Schaum on Newest Techniques

■ J. H. Schaum, editor, MODERN CASTINGS, discussed various metals and showed how new processes and techniques had improved castings and reduced time between raw materials and the finished product.

Certificates of appreciation were made to retiring board members John Uppgren, Northern Ordnance, Inc.; Mel Schroeder, Prospect Foundry Co.; Schuler, American Hoist & Derrick Co.; and Fred Neal, formerly with Smith-Sharpe Co. Bob Johnson, Foundry Supply Co., was given an award for leading the chapter in exceeding its membership quota.

A traveling demonstration trailer-foundry was displayed. Frank Ryan, St. Paul Brass Foundry Co., presented a key to Fred Gordon and Dan Turulla, Minnesota Dept. of Education, symbolizing the chapter's support of the project. The trailer, a practical training aid to industrial arts education, is a combined effort of the Minnesota Dept. of Education, industrial arts teachers, foundries, foundry supply firms and the Twin City Chapter.

Three Indonesian guests attended; Soekarso Atmodipoero, Noerjan Setjodihardojo, R. Soetjipto.

—*Matt Granlund*

Twin City Chapter

Holds Annual Golf Outing

■ No suits or jackets were allowed at the chapter's annual golf outing now transformed into an annual play-day. Bob Johnston Foundry Supply Co., made in three in a row in low net golfers class. Joe Gatske, Progress Co., made it three in a row in low Foundries, Inc., won another title of low gross golfer. Low guest golfer was Pete Sundquist, Superior Separator. Max Demler, Harbison-Walker Refractories, came within three ounces of total weight to win the weight guessing contest. —*Matt Granlund*

Hawaiian theme at **Twin City** annual play day eliminated coats and jackets.

T. E. Barlow, Eastern Clay Products Dept, International Minerals & Chemical Corp., Skokie, Ill., addressed the **Ontario** Chapter in September. Shown with Barlow are Chapter 2d Vice-Chairman **Robert S. M. Gray,** Canadian Westinghouse, Ltd., Hamilton, Ont.; Chapter Chairman **Theodore Tafel III,** American Standard Products (Canada) Ltd., Toronto, Ont.; program chairman **L. H. Burbage,** Otis Elevator Co., Ltd., Hamilton, Ont.
—**Morris Hollingshead**

AFS National Director **L. J. Pedicini** (third from left) then with Congress Drive Div., Tann Corp., Detroit, now with Lester B. Knight & Associates, Chicago, spoke to the Detroit Chapter in September on "How Would You Make It" and showed a movie comparing various casting methods. Others in photo, **V. M. Rowell,** Harry W. Dietert Co.; **F. C. Reicks,** Sutter Products; **W. Lewis,** Great Lakes Foundry Sands. —**J. R. Young**

W. D. Chadwick, Manley Sand Co., Rockton, Ill. (left) addressed Utah Chapter in September. **Everett Backman,** Backman Foundry, Provo, Utah served as technical chairman. Chapter Chairman **Don Rosenblatt,** American Foundry & Machine Co., Salt Lake City, Utah, is on right. —**W. A. Thoresen**

Utah Chapter

Sand Segregation Explained

■ Principles of sand segregation were demonstrated at the September meeting by W. D. Chadwick, Manley Sand Co., Rockton, Ill., through movies showing the behavior of sand under storage, bin charging and discharging. —*W. A. Thoresen*

afs chapter meetings

Birmingham District . . Nov. 13 . . Jefferson Davis Hotel, Anniston, Ala. . . D. Matter, Ohio Ferro Alloys Corp., *"Ductile Iron."*

British Columbia . . Nov. 20 . . Leon's, Vancouver, B. C. . . L. Wilcoxson, International Nickel Co., *"Ductile Iron."*

Canton District . . Nov. 5 . . James B. Clow & Sons, Inc., Coshocton, Ohio . . *Plant Visitation.*

Central Illinois . . Nov. 2 . . American Legion Post 2, Peoria, Ill.

Central Indiana . . Nov. 2 . . Turner's Athenaeum, Indianapolis.

Central Michigan . . Nov. 18 . . Hart Hotel, Battle Creek, Mich.

Central New York . . Nov. 13 . . Drumlins, Syracuse, N. Y.

Central Ohio . . Nov. 9 . . Seneca Hotel, Columbus, Ohio . . W. D. Chadwick, Manley Sand Co., *"Sand Segregation."*

Chesapeake . . *See East Coast Regional Foundry Conference.*

Chicago . . Nov. 2 . . Chicago Bar Association, Chicago . . *Steel Group*: C. G. Mickelson, American Steel Foundries, Mfg. Research Lab., *"Short Time Heat Treatment"; Non-Ferrous Group*: R. Ligocki, Hammond Valve Corp., J. A. Mulvey, Crane Co., J. Curto, Curto-Ligonier Foundry Co. and F. W. Foss, Apex Smelting Co., *"Foundry Scrap, Causes & Cures"; Pattern Group*: H. Nelson, Arrow Pattern & Eng. Co., *"Plastics."*

Cincinnati District . . Nov. 9 . . Engineers' Club, Dayton, Ohio . . J. A. Gitzen, Delta Oil Products Co., *"Mold & Core Sand Additives."*

Connecticut . . Nov. 17 . . American Refractories & Crucible Corp., North Haven, Conn. . . *Plant Visitation.*

Corn Belt . . Nov. 20 . . Marchio's Restaurant, Omaha, Neb.

Detroit . . Nov. 5 . . Wolverine Hotel, Detroit . . E. M. Hinze, E. T. Runge Associates . . *"Cutting Costs in the Foundry." Management Night.*

Eastern Canada . . Nov. 6 . . Mt. Royal Hotel, Montreal, Que. . . R. W. Ruddle, Foundry Services, Inc., *"Correct Use & Latest Development of Exothermic."*

East Coast Regional Foundry Conference . . Nov. 20-21 . . Statler-Hilton Hotel, New York.

Eastern New York . . Nov. 17 . . Panetta's Restaurant, Menands, N. Y.

Metropolitan . . Nov. 2 . . Military Park Hotel, Newark, N. J. . . W. W. Taylor, A. P. Smith Co. and W. C. Stevenson, Atlas Pattern & Model Works, *"Molding for Ferrous & Non-Ferrous Metals."*

Mexico . . Nov. 9 . . Camara Industria Transformacion, Mexico D.F., Mexico.

Michiana . . Nov. 9 . . Elkhart Hotel, Elkhart, Ind. . . *Ferrous Group*: E. E. Woodliff, Foundry Sand Service Engineering Co., *"Almost Every Foundry Can Have Good Molding Sand"; Non-Ferrous Group*: R. A. Payne, Sterling Brass Foundry, Inc., *"Gating."*

Mid-South . . Nov. 13 . . Claridge Hotel, Memphis, Tenn. . . W. L. Adams, Eastern Clay Products Dept., International Minerals & Chemical Corp., *"Pressure Molding for Copper Base Alloys."*

Mo-Kan . . Nov. 19 . . Fairfax Airport, Kansas City, Kans. . . *Joint Meeting with American Society for Metals.*

New England . . Nov. 11 . . University Club, Boston.

Northeastern Ohio . . Nov. 12 . . Tudor Arms Hotel, Cleveland . . *Ferrous Group*: Moderator H. O. Pels, Grabler Mfg. Co., *Panel*: P. F. Hay, Forest City Foundries, Inc., W. Howell, National Malleable & Steel Castings Co., and G. Rosenberg, Crucible Steel Castings Co., *"Casting Cleaning"; Non-Ferrous Group*: F. L. Riddell, H. Kramer & Co., *"Controlling Melting Loss of Brass & Bronze"; Pattern Group*: F. Smale, National Malleable & Steel Castings Co., *"Pattern Design as Related to Gating & Molding."*

Northern California . . Nov. 16 . . Spenger's Cafe, Berkeley, Calif. . . L. Wilcoxson, International Nickel Co., *"Ductile Iron."*

Northern Illinois & Southern Wisconsin . . Nov. 10 . . Beloit Country Club, Beloit, Wis.

Northwestern Pennsylvania . . Nov. 23 . . Amity Inn, Erie, Pa.

Ontario . . Nov. 20 . . Hotel London, London, Ont. . . E. W. Chapman, Cooper-Chapman, Ltd., *"Shell Moulding Process"* and J. A. Lowden, Woods & Gordon, Ltd., *"Management Problems Related to the Foundry."*

Oregon . . Nov. 18 . . Heathman Hotel, Portland, Ore. . . L. Wilcoxson, International Nickel Co., *"Ductile Iron."*

Philadelphia . . Nov. 13 . . Engineers'

Continued on page 128

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TRADEMARK

chapter meetings

Continued from page 126

Club, Philadelphia . . T. E. Barlow, Eastern Clay Products Dept., International Minerals & Chemical Corp., *"Casting Defects as Related to Sand Practice."*

Piedmont . . Nov. 6 . . Vance Hotel, Statesville, N. C. . . Z. Madacey, Beardsley & Piper Div., Pettibone Mulliken Corp., *"Coremaking & Core Blowing."*

Pittsburgh . . Nov. 16 . . Webster Hall Hotel, Pittsburgh, Pa. . . F. H. Dettore, G. E. Smith, Inc., *"Cold Curing Type Binders."*

Quad City . . Nov. 16 . . LeClaire Hotel, Moline, Ill. . . W. R. Jaeschke, Whiting Corp., *"Cupola Operation Fundamentals."*

Rochester . . Nov. 3 . . Manger Hotel, Rochester, N. Y.

Saginaw Valley . . Nov. 5 . . Fischer's Hotel, Frankenmuth, Mich. . . Gray Iron Group: H. Womochel, Michigan State University, *"New Developments in Gray Iron."*

St. Louis District . . Nov. 12 . . Edmond's Restaurant, St. Louis.

Southern California . . Nov. 13 . . Rodger Young Auditorium, Los Angeles . . L. Wilcoxson, International Nickel Co., *"Ductile Iron."*

Tennessee . . Nov. 20 . . Wimberly Inn, Chattanooga, Tenn.

Texas . . Nov. 13 . . Marshall Hotel, Marshall, Texas . . G. DiSylvestro, American Colloid Co., *"Veining & Penetration."*

Texas, San Antonio Section . . Nov. 16 . . Alamo Iron Works, San Antonio, Texas . . J. E. Reedy, Hill & Griffith Co., *"Sand."*

Toledo . . Nov. 4 . . Heatherdowns Country Club, Toledo, Ohio.

Tri-State . . Nov. 13 . . Blackwell, Okla.

Twin City . . Nov. 10 . . Jax Restaurant, Minneapolis . . A. B. DeRoss, Kaiser Aluminum & Chemical Sales, Inc., *"Aluminum Casting Alloys."*

Utah . . Nov. 23 . . Grand View Cafe Provo, Utah . . L. Wilcoxson, International Nickel Co., *"Ductile Iron."*

Washington . . Nov. 19 . . Engineers' Club, Seattle . . L. Wilcoxson, International Nickel Co., *"Ductile Iron."*

Western Michigan . . Nov. 2 . . Bill Stern's, Muskegon, Mich. . . F. P. Ilenda, Diamond Alkali Co., *"CO_2 Molds & Cores."*

Western New York . . Nov. 6 . . Sheraton Hotel, Buffalo, N. Y. . . W. D. Chadwick, Manley Sand Co., *"Sand Segregation" and Film.*

Wisconsin . . Nov. 13 . . Schroeder Hotel, Milwaukee . . *Gray Iron Group*: J. G. Weber, Walter Gerlinger, Inc., *"What Do You Do With Your Shakeout Sand?"; Steel Group*: N. Case, Lindberg Engineering Co., *"Heat Treatment Headaches"; Malleable Group*: R. Richey, A. P. Green Fire Brick Co., *"Air Furnace Refractories"; Non-Ferrous Group*: S. A. Schack, Federated Metals Div., American Smelting & Refining Co., *"Non-Ferrous Foundry Alloys." Pattern Group*: J. Schneider, Schneider Pattern Works, *"Are Schools Training Towards the Pattern Industry?"*

DECEMBER

Canton District . . Dec. 3 . . American Legion Hall, Massillon, Ohio . . T. W. Curry, Lynchburg Foundry Co., *"Ductile Iron Processing."*

Chesapeake . . Dec. 4 . . Engineers' Club, Baltimore, Md., S. J. Pohl, Jackson Iron & Steel Co., *"Use of Silvery Pig in the Cupola."*

Philadelphia . . Dec. 3 . . Sheraton Hotel, Philadelphia . . *Christmas Party.*

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Circle No. 169, Page 15 or 145

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Circle No. 170, Page 15 or 145

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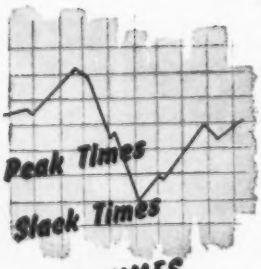
ABC — a strictly independent Merchant Coke Producer



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ABC QUALITY COKE!

Since ABC was formed in 1920, it has maintained its position as a strictly independent merchant coke producer, with no blast furnace or other affiliations having first call on its production.

That is one reason why customers of ABC have always found it a dependable source of supply under all conditions of the market.

ABC's capacity of some 875,000 tons of coke per year from 203 modern Koppers and Becker type ovens enables it to fill orders promptly without ever sacrificing the high quality standards that ABC has always upheld.

ABC maintains at all times a minimum of 60 days' reserve stocks of coal at its large ovens to insure uninterrupted service.

ABC Foundry Coke is produced in two distinct types — standard and malleable — in sizes to meet the most exacting requirements of any foundry operation. Your inquiries are invited.

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Circle No. 171, Page 15 or 145

foundry trade news

AMERICAN DIE CASTING INSTITUTE . . . at its annual meeting held Sept. 16-17 in Chicago elected Gordon C. Curry, Dollin Corp., Irvington, N. J. as president. Walter E. Brown, Kiowa Corp., Marshalltown, Iowa, was elected vice-president. David Laine and W. J. Parker were re-elected as secretary and treasurer. A technical program was also conducted.

NATIONAL FOUNDRY ASSOCIATION . . . at its 61st annual meeting held Nov. 5-6 in New York, elected Arthur G. Hall, Nordberg, Mfg. Co., Milwaukee, as president and Charles Carolin, R. B. Carolin Foundry & Machine Co., Detroit, as vice-president. W. G. Greenlee, Greenlee Foundry Co., Chicago, was elected treasurer. New council members are: William W. Thomas, Straightline Foundry & Machine Co., Emmaus, Pa.; Cline H. Welch, Alloy Cast Steel Co., Marion, Ohio; Don E. DuPerow, Lincoln Brass Works, Detroit; Robert Phelps, Jr., Francis & Nygren Co., Chicago; Thomas H. Tanner, Zenith Foundry Co., Milwaukee and Francis T. O'Hare, O'Hare's Foundry Co., St. Louis. The program featured concurrent sessions dealing with various foundry unions and speakers of national importance.

Empire Brass Mfg. Co. . . . London, Ontario, will soon build a new $750,000 foundry to replace the old one. Induction type melting will be included.

Canada Iron . . . has been awarded a $4,000,000 contract for iron castings in the Toronto East-West subway.

Magnesium casting shipments . . . for June, the second quarter of 1959 and the first half of the year surpassed all figures for the similar periods of last year. All types of castings share equally in the figure. A serious drop in sand casting shipments which occurred in May was reversed in June as the 574 tons shipped climbed back to the average level of the first six months. Die casting shipments continued to climb reaching 255 tons, the highest monthly figure reported since 1957. Permanent mold shipments held up well. Tonnage figures are released by the Magnesium Associated based on information received from the Bureau of Census, U.S. Dept. of Commerce.

Magnaflux Corp. . . . Chicago, since January has conducted 13, five-day sessions in non-destructive testing

Magnaflux training course

covering theory and practice. Since its inauguration in 1956, 364 men have completed the course.

Chrysler Motor Co., Ltd. . . . Windsor, Ontario, will erect a new permanent mold and die-casting foundry. Chrysler and Aluminum Co. of Canada recently formed **Chryalum, Ltd.**, taking in the aluminum smelter at Beauharnois, Quebec, to supply Chrysler with aluminum requirements.

International Casting Corp. . . . New Baltimore, Mich., has purchased property interests in New Baltimore from H. K. Porter Co. The transaction involved 300,000 sq ft of building area for expanding International Casting foundry and pattern facilities.

Crane Co. . . . Chicago, has purchased the 89-year old Chapman Valve Mfg. Co., Indian Orchard, Mass., for a reported $11,400,000. Chapman Valve will be operated as a division of Crane and continue production of the Chapman line and also some Crane products for which Crane has no eastern production facilities. Chapman has 15 district offices throughout the United States.

Hills McCanna Co. . . . Chicago producer of magnesium castings for strategic government work, was toured recently by 33 reserve officers

attached to the Chicago Procurement District, Air Material Command, on a study of production facilities.

Prenco Products, Inc. . . . and Prenco Mfg. Co., formerly of Hazel Park, Mich., have moved to new headquarters at Royal Oak, Mich.

Pressure Blast Mfg. Co. . . . Manchester, Conn., has purchased the Sand Blast Equipment Div., Leiman Bros. Co., Newark, N. J., manufacturer of vacuum air pumps and sand blasting equipment.

Dow Chemical Co. . . . major manufacturing divisions are operating at a level of more than 70 per cent of capacity, and the company may have another sales increase of 10-15 per cent in the present fiscal year, according to president L. I. Doan. Sales reached a new high of $705,000,000 in the fiscal year ending May 31 compared with $636,000,000 in 1958. Earnings of $63,000,000 were 37 per cent higher.

Aluminum Co. of America . . . is starting construction of die casting plant at Edison Township, N.J. Operations are expected to start in the latter part of 1960. The plant will occupy 200,000 sq ft on 76-acre tract.

Shelby Die Casting . . . Shelby, Mass., will start construction this fall on the state's first die casting plant.

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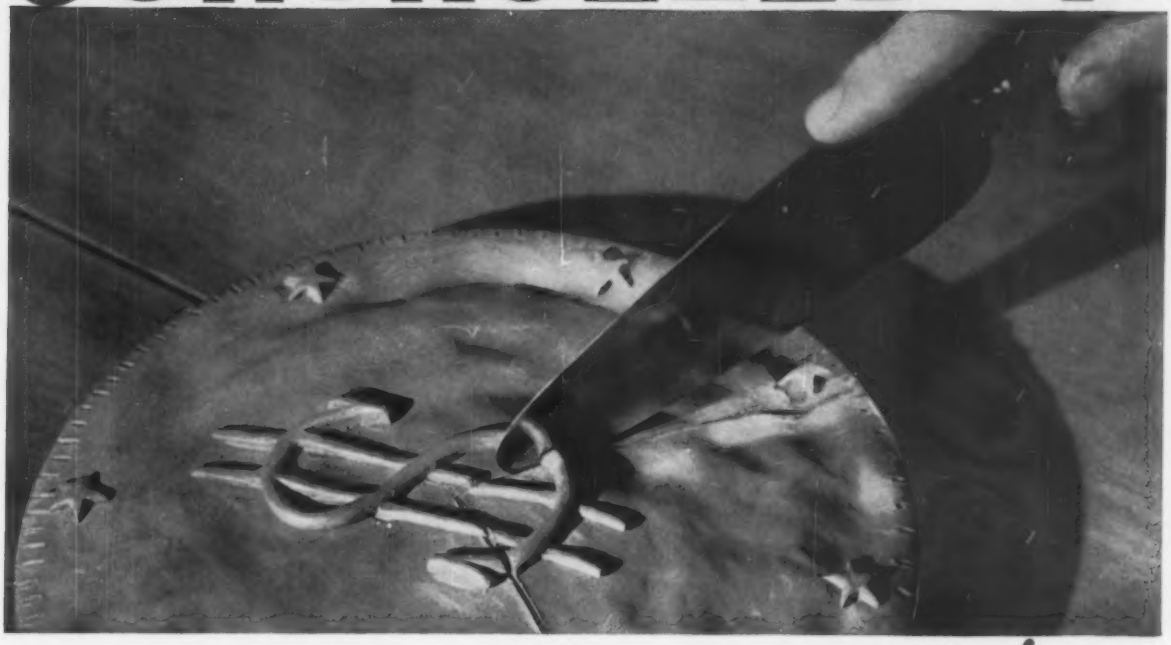

CUT YOURSELF A SLICE OF *profits!*

If you now use hard (chilled) iron abrasives—and almost half of all abrasives used still fall into this category—may we suggest **CONTROLLED "T"®**, with its exclusive and unique properties?

No doubt you selected hard iron abrasives because you wanted: fast cleaning and cutting action (the ability to remove sand and scale) and the "keying" action (where the product will receive further processing). Disadvantages of ordinary chilled shot and grit, of course, lie in their rapid breakdown (causing high consumption) and in their extreme high hardness (causing excessive wear on blades, control cages, impeller, liners, etc.)

CONTROLLED "T"®, made to a specific BHN, is an "iron fist in a velvet glove." Its controlled specifications are such that you enjoy the speed and cutting action of chilled, without the disadvantages of rapid breakdown and high maintenance costs. Savings: as much as 50% on consumption, as much as 40% on maintenance! You can cut yourself a generous slice of profits with these important cost-cutting features of **CONTROLLED "T"®**. If this sounds like a fairy tale, try us! We won't upset your operations with a test, there is a simple and inexpensive way to tell. Cost-conscious customers have been enjoying these extra profits for over a decade!

If you are using ordinary annealed or steel abrasives, you'll want to try our **PERMABRASIVE®**, the pearlitic malleable shot and grit with a controlled hardness range that saves you money through faster cleaning and lower cost per ton. Or **PERMA-STEEL®**, the low cost "work-horse" of the long-life abrasives, may fit your special application perfectly to produce many of the same cost-cutting advantages.

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Circle No. 172, Page 15 or 145

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• The *Thinwal* construction, providing as much as *35% lighter weight* will not spall nor erode in use even at temperatures up to 3250°F. They eliminate slag inclusions, stop rejects, reduce cleaning room time.

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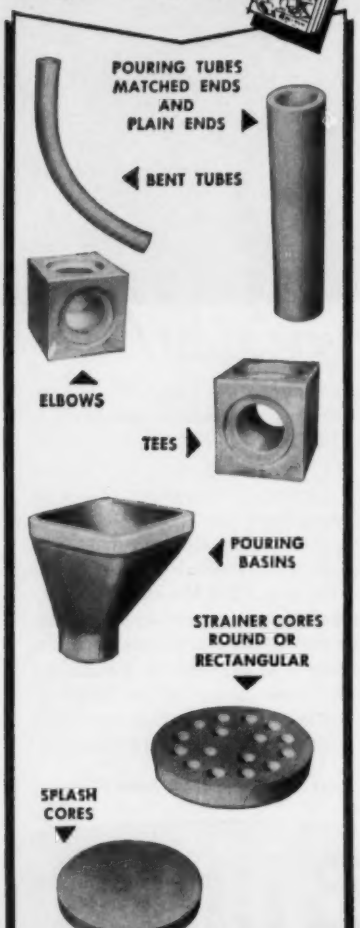

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Circle No. 173, Page 15 or 145

by HERBERT J. WEBER
director—AFS safety, hygiene, air pollution control program

Fables and Foibles

■ I'm sure many of us have heard the fabulous notion that most physicians eventually acquire the disease in which they specialize. The cardiologist gets heart trouble; the dermatologist ends up bald or with acne; and the psychiatrist becomes insane. Without denying anything, I merely ask what happens to the male obstetricians.

There are also current industrial myths that come to my attention from time to time without benefits of verification. Some of these follow:

Periodic Chest X-Rays Are Dangerous

Various stories in the daily press about radioactivity and atomic energy have in some cases produced unfounded fear about the danger of x-ray and radio isotopes.

In one case of record, a man received an accidental overdose of radiation and his neighbors requested his isolation lest he contaminate the entire neighborhood.

A more common situation is the refusal of employees to submit to an annual chest x-ray lest they become sterile or anemic or develop cancer. Some people have refused dental x-ray examination.

Industrial physicians are in accord that the low intensity, split-second radiation dose received over a small part of the body at the time of the annual chest x-ray is insignificant and that the benefits thereby derived from the early detection of any chest diseases far outweigh the effects of such small radiation doses.

On the other hand, the use of fluoroscopes by laymen for fitting shoes is dangerous, and many jurisdictions have barred this practice.

Safety Is Wholly An Intangible

Bunk! Here's a report from Memphis. "In December, 1947 we received notice from our insurance company that they were cancelling our policy. We had paid some $114,000 in premiums over the previous three years. They had paid out 83 per cent in claims during this period." Since 1947 the Company's accident record has improved to such an extent that it now recovers almost 60 per cent of its total workmen's compensation premium (on a retrospective-type policy).

Here's another from Brooklyn. "I just signed a check for $6,952 representing a 'penalty' premium on our workmen's compensation because of our poor accident experience in 1957. In a previous year because of our good experience we received a 'bonus' of $5,200 on our insurance." That's a difference of $12,152 in insurance cost.

Those are tangibles!

The Foundry is an Unhealthful Place to Work

A study of Illinois Foundry conditions made in 1950 by the U. S. Public Health Service showed:

1) That of 1,937 workers x-rayed, only 1.5 per cent involved nodular silicosis.
2) That some cases showing nodular shadows in x-rays may have been due to harmless iron dust rather than to silica dust.
3) That some of these workers had previous exposure to silica dust in mines and quarries.

The Detroit Department of Health reports a steady decrease in cases of nodular silicosis during the years 1940-1954—actually a decrease of 17.6 per cent.

One large insurance carrier that I contacted has not paid a claim in over 15 years for silicosis contracted in a foundry.

Since the early thirties, mechanization and modernization of foundries has progressed rapidly. Today one can observe foundries heated by infrared radiation, dusty materials conveyed in completely enclosed systems, automatic molding, pouring, shakeout and the like and tiled shower facilities superior to those in the average residence.

While Aesop's Fables were narratives intended to emphasize some useful truth, our industrial myths propagate error; cause unfounded fears and in some cases do harm.

As one parody on the William Tell fable put it, after he shot the apple from his son's head: "That's why today every apple has a hole."

60 CYCLE INDUCTION MELTING at ALUMINUM FOILS, INC.

AJAX-JUNKER Coreless 60 Cycle Induction Furnace

Economically Melts Aluminum Foil, Chips, and Sawings.

The 700 kw AJAX-JUNKER coreless induction furnace at the Jackson, Tenn., plant of ALUMINUM FOILS, INC. — specialists in high-quality aluminum foil, coiled sheet, and super-purity aluminum pig — is the largest unit of its type in operation in this country. With a total capacity of 7000 lbs of aluminum, the furnace is capable of melting 3200 lbs per hour.

The AJAX-JUNKER furnace at this company melts plant scrap consisting of foil, scalper chips, and sawings, materials requiring special attention when using conventional furnaces. With the AJAX-JUNKER furnace and its strong inherent stirring action, no labor is required for 'puddling'. One man controls the entire operation.

Average metal losses are below 2% in this installation where experience with other furnace types showed average losses of over 6%. Accurate temperature control, dependability, and uniformity of alloy composition are further features of this unit. ALUMINUM FOILS are also producing hardener alloys directly from plant scrap with a minimum of effort and a maximum of alloy accuracy.

The AJAX-JUNKER 60 cycle induction furnace is an ideal tool for many different applications, melting ferrous and nonferrous metals. Our engineers will be glad to study your melting requirements. Write to AJAX ENGINEERING DIVISION, Trenton 7, N. J., for Bulletin R 58.

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Circle No. 174, Page 15 or 145

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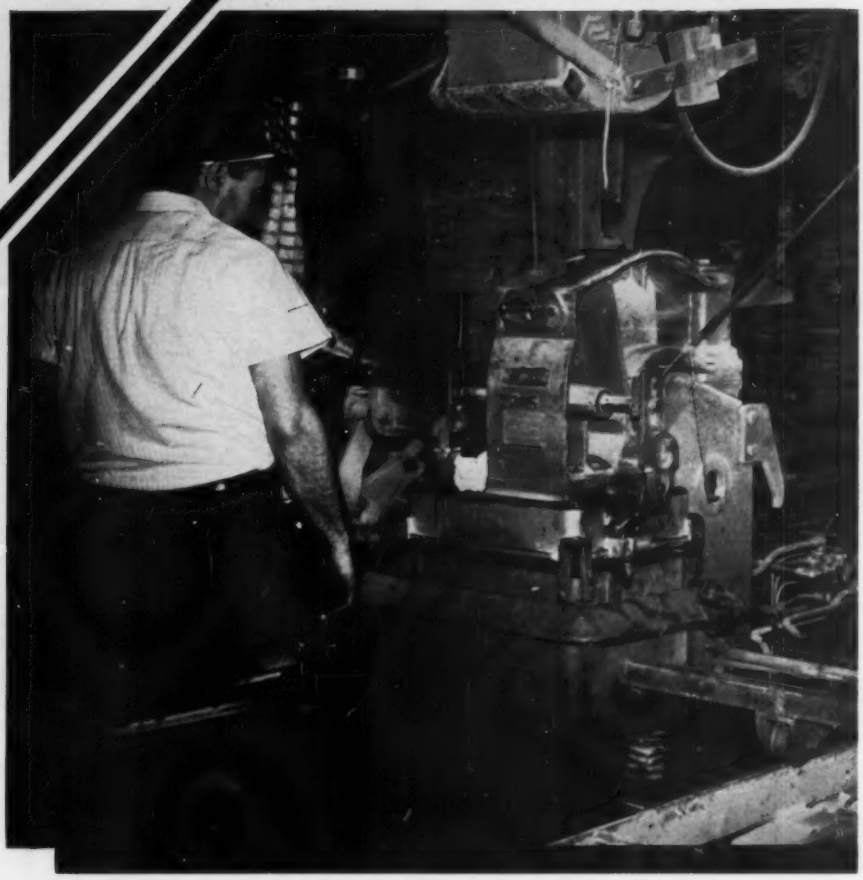
IN IRON AND NON-FERROUS FOUNDRIES THRU-OUT NORTH AMERICA

The H.E.B. *FLASKLESS* Machine



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- OWN HYDRAULIC POWER PACK
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Circle No. 175, Page 15 or 145

"Give me lower operating costs"

Said the Boss

"Give me fewer rejects"

Said the Superintendent

"Give me more uniform coke"

Said the Foundryman

Order KOPPERS Premium Foundry Coke

Premium quality foundry coke! That's exactly what Koppers delivers car-after-car. Made from the highest quality West Virginia coals, scientifically blended and baked the right length of time, Koppers Premium Foundry Coke is absolutely *uniform* in *size, strength, structure* and *chemical analysis.* With its higher carbon content, Koppers Coke enables the foundryman to maintain a higher temperature range, thus increasing the the cleanliness of the iron. This in turn, helps reduce fuel consumption and means lower operating costs all around. Next time *order* Koppers Premium Foundry Coke. Available anywhere in the U.S. or Canada in sizes to meet your needs. Koppers Company, Inc., Pittsburgh, Pa.

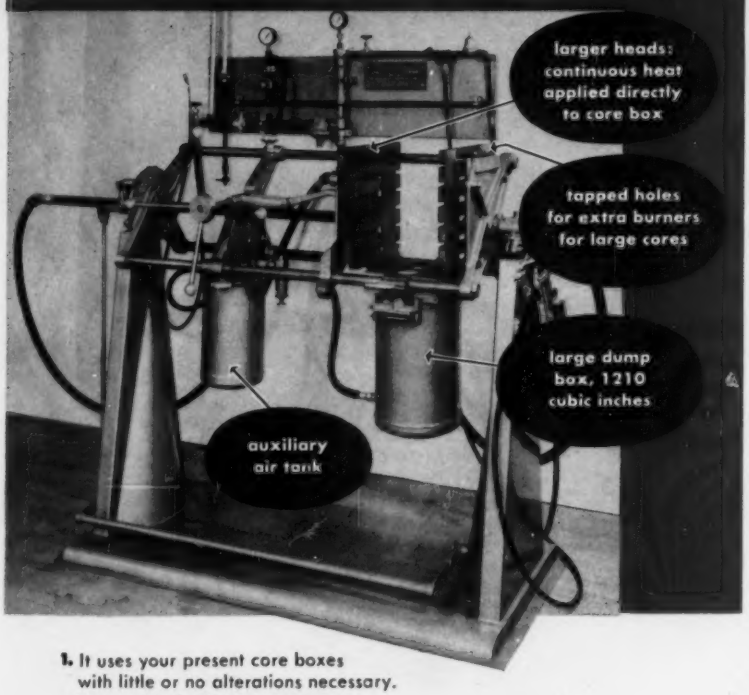
WE CHECK EACH DAY'S RUN to make certain you get foundry coke of the exact size and chemistry that is most efficient for the job. Analyses are available to your foundry on request.

Circle No. 176, Page 13 or 145

The "200 SERIES"

'DEPENDABLE'

SHELL CORE MACHINE


larger heads: continuous heat applied directly to core box
tapped holes for extra burners for large cores
large dump box, 1210 cubic inches
auxiliary air tank

1. It uses your present core boxes with little or no alterations necessary. No need to build new core boxes.
2. Continuous heat applied directly to back of core box. Thin sections most desirable. Fast and efficient.
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8. Shell cores produced offer Unexcelled Permeability . . . Collapsibility . . . Accuracy . . . Easy Shake-Out.
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10. Your Dependable Shell Core Machine comes completely equipped with accessories and assembled ready to operate. Just hook up to gas and compressed air lines. Shipping weight, crated, 500 lbs.

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Frank H. Jefferson, Inc. *Seattle 4, Wash.*
Sierra Foundry Supply Co. *San Gabriel, Calif.*
Shallway International Corp. *Los Angeles, Calif. and Crawley, England*
W. O. McMahon *Birmingham 9, Ala.*
La Grand Industrial Sup. *Portland, Oregon*
St. Louis Coke & Foundry Sup. *St. Louis, Missouri*
Sinclair-Brandt Co. *Houston 21, Texas*
Smith-Sharpe Co. *Minneapolis 14, Minn.*
Barker Foundry Sup. Co. *So. San Francisco, Calif.*

Circle No. 177, Page 15 or 145

product report . . .

New cast plastic matches the density and feel of wood. Made by Furane Plastics, Inc. and termed "Masterlite," this product may be shaped by the patternmaker on conventional woodworking tools as easily as wood. The Masterlite wood has no grain, is homogeneous and will not swell or shrink with humidity changes. A typical pattern fabricated from the new plastic is illustrated below. The properties are defined by the data contained in Table 1. The material carves easily with a penknife, nails like wood and handles nicely on a jointer, sander or planer.

TABLE 1
Physical Properties of Masterlite

Average Density	35-40 lb/cu ft
Ultimate Compressive Strength	4700 psi
Deformation at Ultimate Compression	30%
Water Absorption (Two-hour Boil)	2.5%
Modulus of Elasticity in Compression	100,000 psi
Grain Direction	None
Machining	Excellent

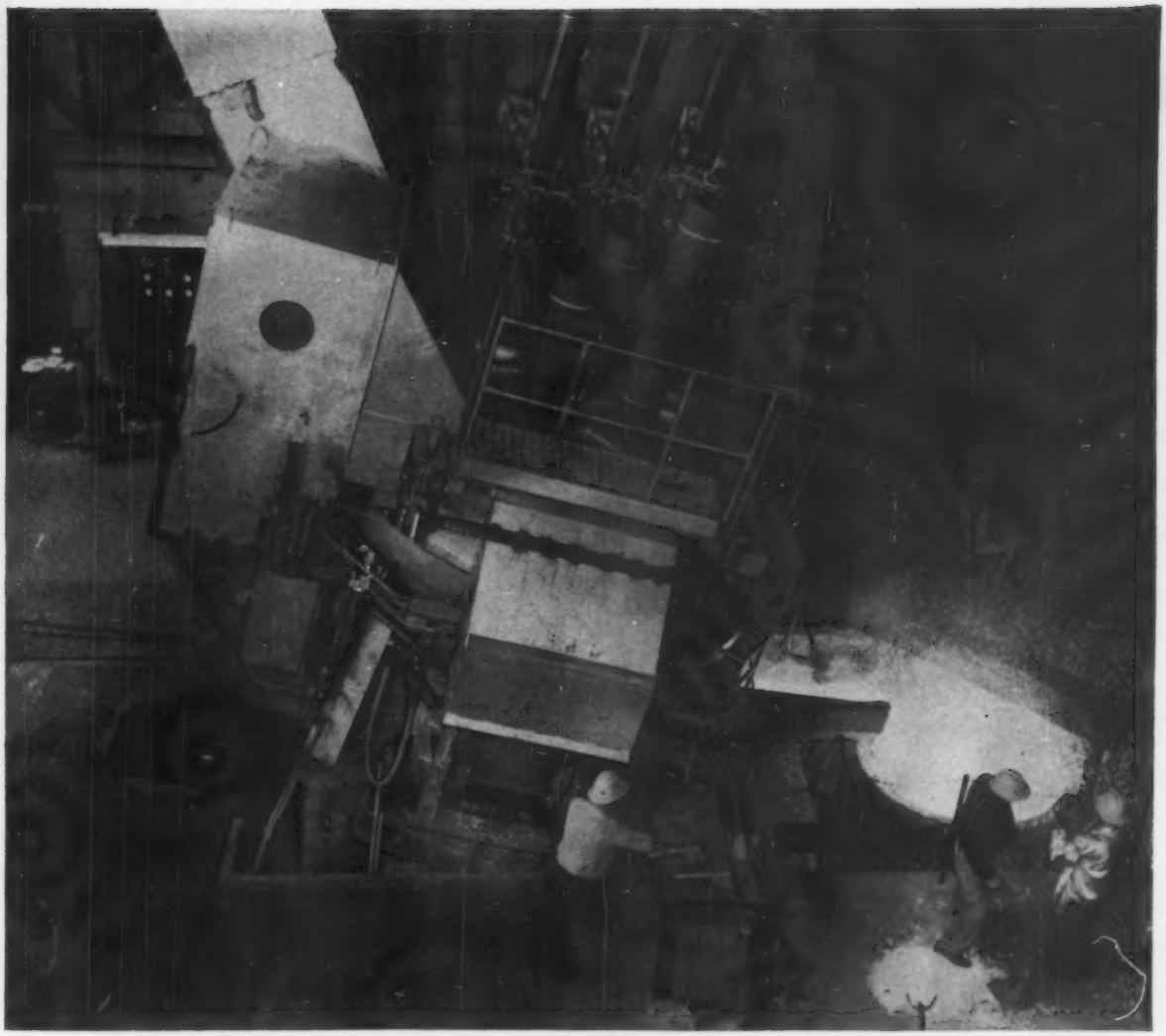
This plastic material costs several times more than mahogany on a per pound basis. Higher material cost is justified if humidity and dimensional changes necessitate replacement of wood patterns. Becaues Masterlite is a cast plastic sheet, pattern construction is not limited in thickness, length or width.

Cementing sections of Masterlite together is a relatively simple task. Cured joints have all the characteristics of the rest of the panel. These same agents may also be used for the potting of drill bushings, studs, sleeves or guide bushings. Secured firmly into the pattern, they constitute useful tooling aids to the patternmaker.

The plastic can also be cast approximately to size to minimize the machine-shop time. If multiple, duplicate patterns are involved, the methods of gel coating and laminating within the mold can be employed effectively and economically.

Some pattern shops prefer to rough-cast their Masterlite patterns and complete the fabricating with conventional woodworking equipment. Not only is there a practical utilization of material and minimization of waste, but also considerable reduction in machining time when the rough cast patterns approximate final dimensions. Colors may be introduced into the casting formulation and color coding achieved without an extra finishing step. Working with this wood-like substance will pose on problem to the ingenious patternmaker who will find his own techniques and specific uses for the material.—John Delmonte, Furane Plastics, Inc.

For More Information, Circle No. 33, Page 15



RUGGEDNESS...

A MAJOR FACTOR IN THE LOW MAINTENANCE AND HIGH AVAILABILITY OF LECTROMELT FURNACES

When you're selecting an electric furnace, compare design details and you'll note the heavier, sturdier construction that Lectromelt provides. This pays off for you in *service*—Lectromelt furnaces enjoy a world-wide reputation for high availability and low maintenance.

Lectromelt is the world's most experienced builder of electric furnaces. Whether your needs are for 200-pound or 200-ton capacities, it will pay you to get Lectromelt's recommendations when planning additions or replacements. Catalog 10 contains full information.

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Circle No. 178, Page 15 or 145

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L. J. Pedicini

H. M. Patton

R. J. Mulligan

W. J. MacNeill

F. C. Nilson

F. X. Bujold

let's get personal

Frank X. Bujold . . . formerly, manufacturing manager of foundries, Engine & Foundries Div., Ford Motor, Cleveland, has been named general manager, Frauenthal Div., Kaydon Engineering Corp., Muskegon, Mich.

John Nieman . . . has joined Production Pattern & Foundry Co., Chicopee, Mass., as assistant to the president. He was recently conferred the B.D. degree by the University of Chicago Divinity School and was ordained by the United Church of Christ in June. His ordination commisions him to work in industry while retaining an ordained status in the church.

Burton E. Seaquist . . . is now assistant controller, Minneapolis Electric Steel Castings Co., Minneapolis.

Fred C. Nilson . . . is now a special service consultant with Westover Corp. & Associates, Milwaukee. He has more than 40 years experience in plant layout and materials handling. **Wm. J. MacNeill** has also joined Westover Corp. & Associates and has over 40 years experience in malleable, gray iron, nonferrous operations and management.

Thomas W. Teetor . . . formerly with Federal Malleable Co., West Allis, Wis., and later a fellowship student at Purdue University, is now general manager, Golden Foundry Co., Columbus, Ind. **Robert L. Clark**, formerly with Century Foundry Co., St. Louis, is now chief metallurgist.

John N. Davenport . . . has been elected president, Fulton Foundry & Machine Co., Cleveland, and **Edward Burkholder** has been named vice-president and sales manager. Davenport joined Fulton Foundry in 1946 and was elected secretary in 1954. Burkholder was formerly executive vice-president, Banner Iron Works, St. Louis.

Louis M. Lund . . . is field representative in Minnesota for Federal Foundry Supply Div., Archer-Daniels-Midland Co., Cleveland, succeeding **Richard Szarz** now in the Chicago territory.

Karl R. Braddock . . . is western Pennsylvania representative for Frederic B. Stevens, Inc., Detroit. He had been previously employed by Westinghouse Air Brake Co., Wilmerding, Pa.

Russell A. Hedden . . . has been appointed works manager of manufacturing, Industries Group, Allis-Chalmers Mfg. Co., West Allis, (Wis.) Works. He was formerly works manager of the company's York (Pa.) Works and succeeds **E. W. Bonness** now consultant to the director of manufacturing, Industries Group.

Ralph W. Barker . . . has been named as general foundry superintendent Superior Foundry Div., Superior Foundry, Inc., Cleveland. For the past eight years he was melting superintendent of Ford Motor Co. Cleveland Foundry. **Robert K. Kelley** has been named as general foundry superintendent, Allyne-Ryan Div., Superior Foundry Inc. For the past five years he was chief inspector and foundry foreman at the Superior Foundry

R. W. Barker

R. K. Kelly

Div. and assistant to the plant manager at the Allyne-Ryan Div. **James R. Sims** has been named as employment manager of the Superior Foundry and Allyne-Ryan divisions. Sims joined Superior Foundry, Inc., as shop employment manager in 1956. **Wallace R. Metzger** has been named as personnel manager of Superior Foundry and Allyne-Ryan divisions. He joined Superior Foundry, Inc., in 1955 and has served as personnel manager of the main plant.

R. J. Mulligan . . . 1958-59 AFS Twin City Chapter Chairman and formerly supervisor of foundry products research and development, Archer-Daniels-Midland Co., has been named general sales manager, Federal Foundry Supply Div., Archer-Daniels-Midland Co. He succeeds **Anton Dorfmueller, Jr.**, who has been named as assistant general manager.

L. J. Pedicini . . . AFS National Director, formerly manager, manufacturing engineering, Congress Die Casting & Drive Div., Tann Corp., Detroit, is now associated with Lester B. Knight & Associates, Chicago. Initially he will spend several months in the Knight office at Zurich, Switzerland.

H. M. Patton . . . AFS National Director has been named works manager, American Hoist & Derrick Co. in charge of operations of the company's St. Paul Minn., plants. He will continue as president of Valley Iron Works in St. Paul which was acquired by American Hoist last year. **Richard W. Wilson**, formerly assistant manager, is now foundry manager for American Hoist.

S. Dean Shoper . . . has been appointed works manager, Mexico Refractories plant, Mexico, Mo. Since 1957 he has served as general superintendent of Mexico facilities now operated as part of the Kaiser Chemicals & Refractories Div., Kaiser Aluminum & Chemical Corp., Oakland, Calif. **Robert W. Stephens** has been named as plant superintendent of the new Midland, Mich., refractory plant of Kaiser Chemicals & Refractories Div. The plant is scheduled to start operations about April, 1960.

Fred Menzel . . . has been named national sales manager, Dependable shell Core Machines, Inc., Portland, Ore. Menzel had been plant manager of the Portland branch, Rich Mfg. Co. for the past 11 years.

E. K. Leavenworth . . . has been named as a vice-president, Climax Molybdenum Co. of Michigan and will headquarter at the company's Coldwater, Mich., plant where he serves as works manager.

Donald R. Smith . . . is now plant manager, Ironton Fire Brick Co., Ironton, Ohio. His duties will include operation of the Ironton plant and mines at Soldier, Ky. He was formerly manager of the special products division.

Robert G. Bottorf . . . has been ap-

Continued on page 143

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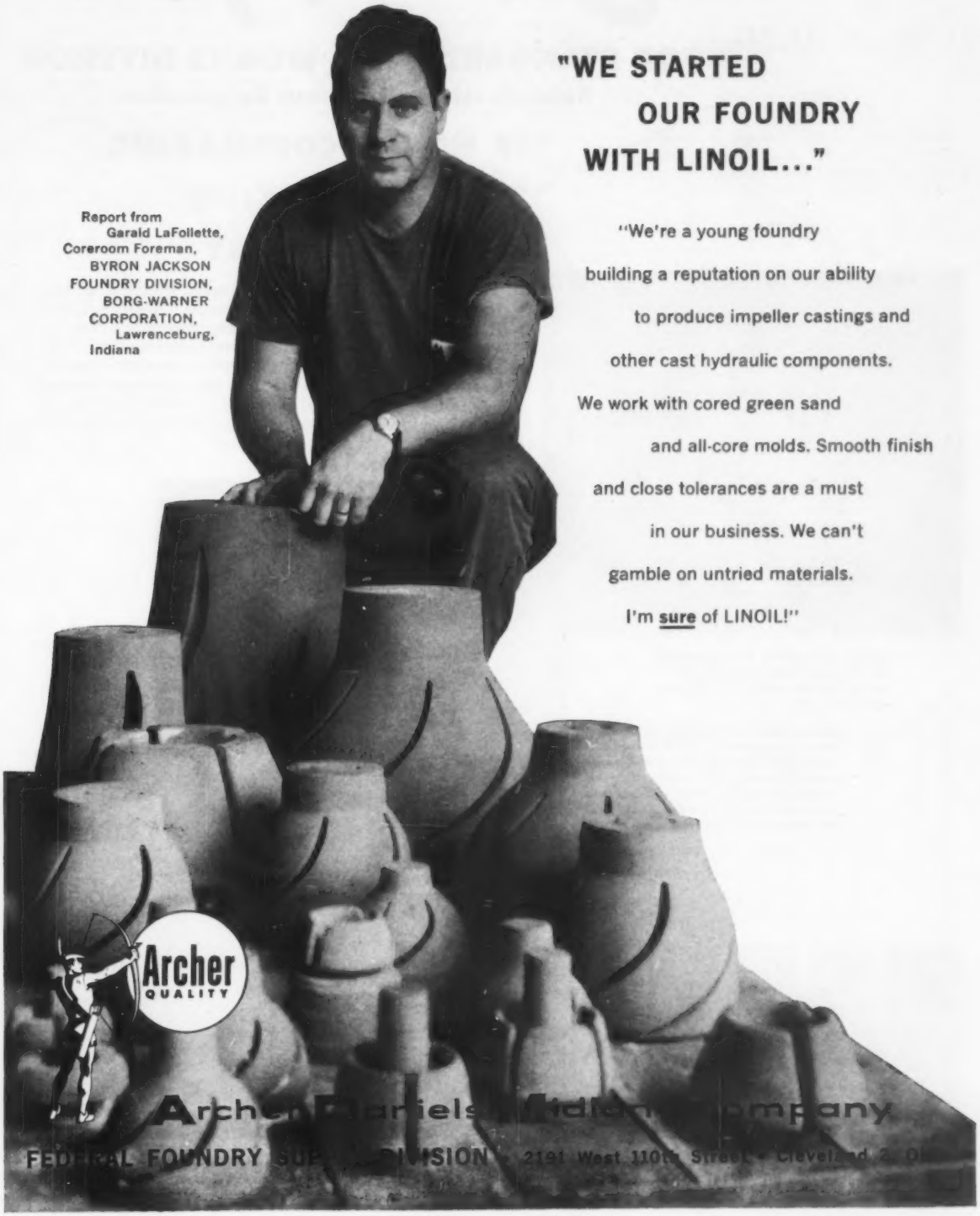

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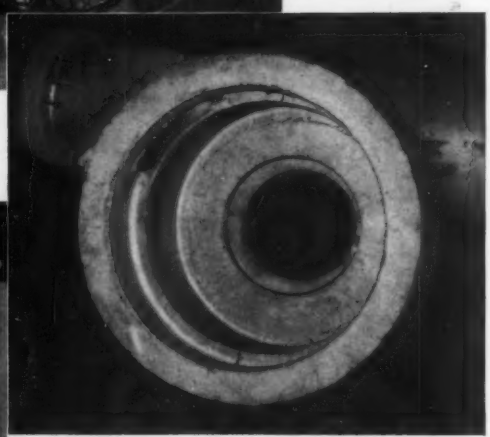

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Circle No. 182, Page 15 or 145

let's get personal

Continued from page 139

pointed sales manager of Colmar, Pa., plant of Link-Belt Co. He has been with Link-Belt since 1938.

William H. Combs . . . has been elected a vice-president, Great Lakes Carbon Corp., New York. He will continue to serve as general manager of the company's Missouri & Chemical Div. with offices in St. Louis.

Leon C. Koenig . . . has been named as vice-president of manufacturing, Lindberg Engineering Co., Chicago. He is a company founder and has been assistant secretary and plant manager.

Fred Hodgson . . . has been promoted to chief product engineer, Eaton Mfg. Co., Foundry Div., Vassar, Mich. He has been associated with Eaton since 1954.

E. F. Helminiak . . . has been named manager, Chicago district, Union Carbide Metals Co., Div., Union Carbide Corp. Other sales department promotions are: **Arthur Herbener,** Cincinnati; **F. A. Stephens,** Detroit; **J. G. Holmes** and **O. G. Specht,** assistant managers, Pittsburgh region; **S. L. Jackson,** assistant manager eastern region with headquarters in Phillipsburg, N. J.

George Vingas . . . recently appointed as foundry research engineer for Magnet Cove Barium Corp., has been assigned to the Foundry Div. headquarters at Des Plaines, Ill. The company is constructing a foundry research laboratory at Rolling Meadows, Ill.

Hugh MacArthur . . . president Connecticut Coke Co. since 1943 and a vice-president of its parent organization, Eastern Gas & Fuel Associates, has retired but continues as a director. **W. B. Ross,** vice-president, Eastern Gas & Fuel Associates, has been elected president of the Connecticut Coke Co. and **Thomas E. Thibeau,** vice-president of Connecticut Coke Co. has been elected vice-president and general manager of the coke company and general manager of the Connecticut Coke Sales Div. of Eastern.

W. R. Moggridge . . . is now quality control manager, Canada Iron Foundries, Ltd., Toronto, Ont. He was formerly manager of quality control at Ford Motor Co. of Canada, Ltd., Windsor, Ont.

John F. Partridge . . . assistant secretary, American Steel Foundries, has been elected secretary and counsel succeeding **Orrin B. Garner** who retired.

Herbert W. Stuart, director of quality control, United States Pipe & Foundry Co., Burlington, N. J., has been honored by A.S.T.M. for . . . "Recognition of leadership and unfailing support of numerous A.S.T.M. technical and administrative activities, especially on cast iron." He is a member of the AFS Philadelphia Chapter.

Edward A. Margus . . . has been appointed as assistant director, product engineering, Cooper Alloy Corp., Hillside, N. J. He joined Cooper Alloy in 1953 as an engineer and in 1958 was named chief designer.

Ralph Rennie . . . is now field sales engineer, New England territory, for Casting Engineers, Div. Consolidated Foundries & Mfg. Corp., Chicago. He formerly served the company as a sales representative through an independent organization. Rennie will headquarter in South Windsor, Conn.

Lawrence G. Blackmon . . . has been appointed manager, Phoenix Works of the Capital Foundry Div., National Malleable & Steel Castings Co. **Robert D. Everett** replaces Blackmon as manager of the company's Sharon (Pa.) Works, part of the Transportation Products Div. and **Edward O. Spahr** replaces Everett as general superintendent at Sharon.

Ronald K. Meyers . . . is now foundry sales engineer, Delhi Foundry Sand Co. with offices in Cleveland, covering northern Ohio.

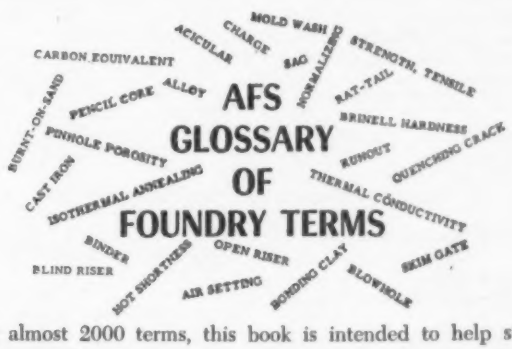
Manuel Tama . . . is now vice-president, Ajax Engineering Div., Trenton, N. J. and **Melvin A. Raney** has been appointed vice-president of the Ajax Electrothermic Div., also in Trenton, N. J. Both are divisions of Ajax Magnethermic Corp., Youngstown, Ohio, formed earlier this year through the joining of the two Ajax companies.

obituaries

Hubert C. Stone, a director and general superintendent, Belle City Malleable Iron Co. and Racine Steel Castings Co., Racine, Wis., died Sept.1 of a heart attack.

John A. Marr, 76, died Aug. 13, after an extended illness. His foundry career began in 1904 and included positions as works manager at Chicago Steel Foundry, Fort Pitt Steel Castings Co. and Locomotive Finished Material Co., where he was at the time of his retirement in 1946.

Eldon M. Altman of Hamilton Foundry, Inc., Hamilton, Ohio, died Aug. 10. He had been active in the AFS Safety, Hygiene & Air Pollution Control Program.



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Vibrating screens . . . and foundry shakeouts described and illustrated in new book. Link-Belt Co.
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Flexible shaft . . . machine catalog describes units designed for "small work" foundry grinding, finishing and deburring. Foredom Electric Co.
For Your Copy, Circle No. 72, Page 145

Manganese . . . in cast iron brochure covers function of the metal in furnaces and ladle additions and recovery in furnaces and ladles. Ohio Ferro-Alloys Corp.
For Your Copy, Circle No. 73, Page 145

Electric hoists . . . described in catalog No. H-59. American Engineering Co.
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Snagging wheels . . . brochure includes recommendations for grinding castings made of steel, malleable iron, gray iron and non-ferrous alloys. Simonds Abrasive Co.
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Driver training . . . instruction manual for training drivers of industrial trucks is yours free of charge. Automation Transportation Co.
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Pallet trucks . . . 2000-lb capacity, lightweight hydraulic type, described in new circular. Lewis-Shepard Products, Inc.
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Synthetic resin . . . for malleable and nodular iron discussed in technical bulletin. Reichhold Chemicals, Inc.
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Oil field . . . and gas field applications for steel castings featured in product design study. Five applications discussed. Steel Founders' Society of America.
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Plunging ladle . . . for producing nodular iron by plunging method. Send for free data sheet. Industrial Equipment Co.
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Hot sands . . . and how they cause casting imperfections is subject of brochure which is yours for the asking. American Colloid Co.
For Your Copy, Circle No. 84, Page 145

Furnace charges . . . pre-alloyed for foundries discussed in brochure. Security Alloys Co.
For Your Copy, Circle No. 85, Page 145

Castings cleaning . . . handbook is a new publication concerning chemistry and techniques of metal cleaning; 28 pp. Oakite Products, Inc.
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Monorail . . . and crane equipment featured in 54-p brochure showing examples of cost-cutting operations in actual plant situations. Features section on foundries. Louden Machinery Co.
For Your Copy, Circle No. 87, Page 145

Bonded surface . . . for green sand cores and molds is achieved by an air-drying spray said to show excellent penetration and offer surface with more resistance to washing action in pouring. United Oil Mfg. Co.
For Your Copy, Circle No. 88, Page 145

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For Your Copy, Circle No. 92, Page 145

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For Your Copy, Circle No. 93, Page 145

Noise Reduction in Small Shops
For Your Copy, Circle No. 94, Page 145

High Temperature . . . cements, mortars and coatings co-ordinated to foundry furnaces detailed in 18-p brochure. Mexico Refractories Co.
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Safety cup wheels . . . for portable grinding in foundries listed as to construction, specifications and recommendations for use in 2-p folder. Carborundum Co.
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New nickel-base alloy . . . developed as container material for molten fluoride salts. Said to show promise for continuous operation up to 1800 F., and is

available as sand, shell and investment castings. Haynes Stellite Co.
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Telephone dialing codes . . . for direct distance dialing throughout the United States are offered to you in chart form. Describes how to dial and lists code numbers for each state. Ohio Seamless Tube Div.
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Alloyed steel . . . what are the principal alloying elements in steel? Informative booklet, 18 pp, covers in detail carbon steel, alloy steels and ferroalloys. United States Steel Corp.
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Run-in lubrication . . . outlined for motors and machinery being "broken in." Brochure also covers lubrication during assembly of machinery. Acheson Colloids Co.
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Magnesium alloys . . . of thorium and rare-earth-metal families discussed relative to shop techniques and recommended practices for working these elevated-temperature alloys. Magnesium Products Sales Dept., Dow Chemical Co.
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Retractable power dock . . . adjustable four ways, described in leaflet. *Hartman Metal Fabricators, Inc.*
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2	14	26	38	50	62	74	86	98	110	122	134	146	158	170	182	194	206	218
3	15	27	39	51	63	75	87	99	111	123	135	147	159	171	183	195	207	219
4	16	28	40	52	64	76	88	100	112	124	136	148	160	172	184	196	208	220
5	17	29	41	53	65	77	89	101	113	125	137	149	161	173	185	197	209	221
6	18	30	42	54	66	78	90	102	114	126	138	150	162	174	186	198	210	222
7	19	31	43	55	67	79	91	103	115	127	139	151	163	175	187	199	211	223
8	20	32	44	56	68	80	92	104	116	128	140	152	164	176	188	200	212	224
9	21	33	45	57	69	81	93	105	117	129	141	153	165	177	189	201	213	225
10	22	34	46	58	70	82	94	106	118	130	142	154	166	178	190	202	214	226
11	23	35	47	59	71	83	95	107	119	131	143	155	167	179	191	203	215	227
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Continued on page 148

"Bakeless" cores and molds in 20 seconds

Liquid Carbonic's Improved CO_2 Process Sparks Revolutionary Advances in Core-Hardening

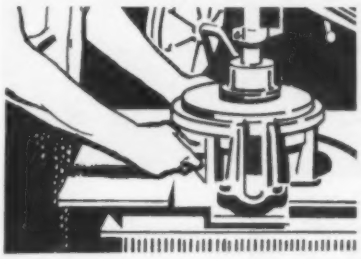
Requests for "we-need-it-tomorrow" deliveries seem to cram a foreman's order pad every day. Until now, immediate delivery has been a source of concern to the foundry industry because of lengthy baking and drying procedures.

Because of this, more and more foundries are adopting the bakeless CO_2 core-hardening process. Intricate cores can be made with CO_2 in a matter of seconds; completely finished cores (rammed, gas-hardened and removed) are produced in less than three minutes. Thus, CO_2 has become the propelling ingredient in production boosts throughout the country—so much so that it promises to soon become *the* method of core-hardening.

Speed . . . And Other Advantages

Actually, it's simply a matter of supply and demand: the great demand today is for speed—therefore, CO_2. It doesn't just end there . . . the CO_2 process makes other core-making techniques old-fashioned. For example:

1. Eliminates baking ovens and core dryers
2. Better dimensional stability
3. Smoother finish on castings
4. Excellent shakeout and collapsibility
5. Reduces production costs
6. Minimizes rejects
7. Eliminates excessive core inventory
8. Expedites emergency orders
9. Simplifies core design
10. Adaptable for automation



CO_2 Ideal for Mold-Hardening, Too

In addition to these advantages, many foundries have discovered that CO_2 is just as beneficial in mold-making as it is in core-hardening. Dry sand molds sometimes require baking at 300° to 400° F. for periods up to 75 hours; the CO_2 process can do the same job at time-savings up to 95%. CO_2 molding also can save as much as 90% in machine-shop costs, cuts labor requirements, and works equally well on both large- and small-size molds.

Although CO_2 is a relative newcomer to core-making, many improvements have already been made

since it was first introduced. A trained staff of Liquid Carbonic engineers have been working for years to improve the CO_2 process. The combination of research, development, and daily shop practice has brought the CO_2 process up to today's high standards, making it the preferred method of core- and mold-hardening in today's foresighted foundries. Call your Liquid Carbonic representative today and have him show you how CO_2 can improve your production!

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Circle No. 183, Page 15 or 145

"Rotoblast Steel Shot cuts abrasive costs in half!"

Rotoblast Steel Shot reduces abrasive consumption more than 50% at Atlantic Steel Castings

"Talk about a rugged cleaning job!" says Mr. William Burrows, Plant Manager, Atlantic Steel Castings Co., Chester, Pa. "Our castings are carbon and low alloy steel, running as big as eight tons each. We used to think we had a good abrasive until we tried Rotoblast Steel Shot. Our tests proved (and we double-checked them to make sure) that Rotoblast cut our shot consumption per wheel hour to less than half. That means our abrasive costs are cut exactly in half! Also we've found that Rotoblast gives us the kind of finish that our customers in the railroad, steamship, steam turbine* and automotive industries demand."

Prove Rotoblast's cost-cutting qualities in *your* plant. To arrange a trial, talk to your Pangborn man or write PANGBORN CORPORATION, 1300 Pangborn Blvd., Hagerstown, Md. *Manufacturers of Blast Cleaning and Dust Control Equipment — Rotoblast Steel Shot and Grit.*

**The toughest castings in industry to clean.*

Pangborn

ROTOBLAST® STEEL SHOT AND GRIT

Circle No. 184, Page 15 or 145

for the asking

Continued from page 146

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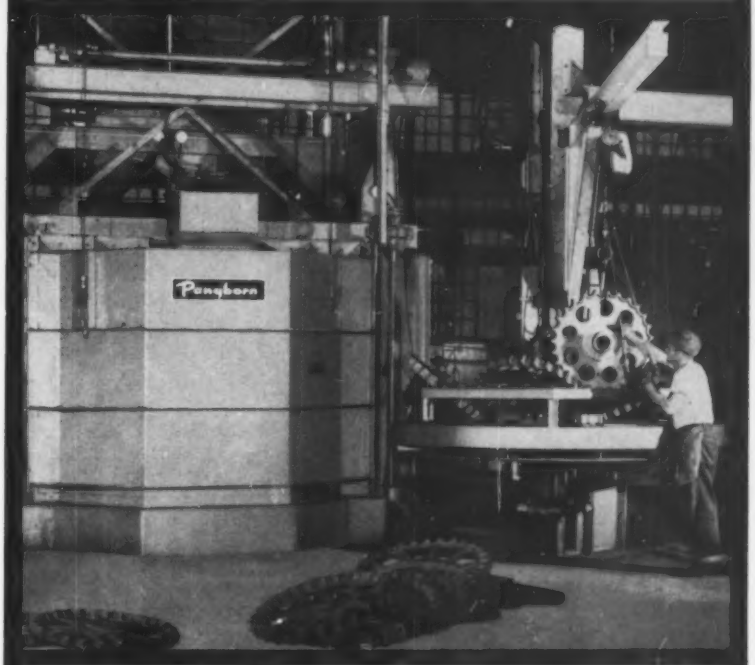
DOUBLES CLEANING CAPACITY!



Pangborn Table Room does twice the work at Harrison Steel Castings!

Two basic features of the new Pangborn "LM" Table Room at Harrison Steel Castings Co., Attica, Ind., explain the firm's doubled capacity in the cleaning department.

First: Twin work tables—one rotating in the blast cabinet while the other is reloaded—clean pieces up to 8' diameter continuously. These tables handle smoothly . . . are easily pushed by hand. Their weight while loading is supported by a stationary floor pedestal (rather than door hinges) for long life and trouble-free operation.

Second: The "LM" Table Room utilizes two Rotoblast wheels throwing a total of 100,000 lbs. of abrasive per hour. The result is a tremendous concentration of blast power for quick cleaning . . . positioned for complete, thorough work coverage.

The cleaning speed and operating ease of the Pangborn Table Room have proved the value of this machine at Harrison Steel Castings. If *you* must maintain production schedules in cleaning large, awkward or heavy pieces, send for Bulletin 805. Write PANGBORN CORPORATION, 1300 Pangborn Blvd., Hagerstown, Md. *Manufacturers of Blast Cleaning and Dust Control Equipment—Rotoblast Steel Shot and Grit.*℠

Pangborn

Cleans it fast with ROTOBLAST®

Circle No. 185, Page 15 or 145

IT'S UP TO YOU!

The students who are interested in the foundry industry today are the industry's management of tomorrow.

One of our jobs, as the Foundry Educational Foundation, is the encouragement of, and assistance to, these students.

Over the past nine years, as you can see from the accompanying chart, F.E.F. has made great strides in that direction. Sixty-four departments now require students to study the cast metals industry, as compared to only twenty in 1947.

This advancing trend will assure a continuing flow of capable, well-educated young men into our industry . . . **providing** your interest and financial support are maintained now and in the future.

DEPARTMENTS REQUIRING CAST METALS STUDY

20 1947

64 1958

Write for our new booklet, "Let's Look Ahead".

You'll be glad you did.

Foundry Educational Foundation

1138 TERMINAL TOWER BUILDING • CLEVELAND 13, OHIO

Space contributed by Modern Castings as another service to the metal castings industry.

Circle No. 186, Page 15 or 145

THE role of the Designer is one of far-reaching significance in the foundry industry. In addition to his ability to supervise the design and specifications of castings, he must have a thorough knowledge of the properties of the iron and the casting techniques to be used, the service conditions of the castings, and other factors such as the quality, cost and appearance of the finished castings.

Pittsburgh Coke and Chemical is proud to salute the gray iron foundry Designer. It is equally proud to serve as a basic supplier of two quality products for the nation's foundry trade . . . NEVILLE Pig Iron and NEVILLE Foundry Coke.

An enlarged (11½" x 11") reproduction of the above etching, suitable for framing, will be sent without cost upon request. Similar etchings from the previous ads of this series, featuring the Pattern Maker, the Molder, the Melter and the Metallurgist, are also available.

Neville Pig Iron and Neville Coke for the Foundry Trade

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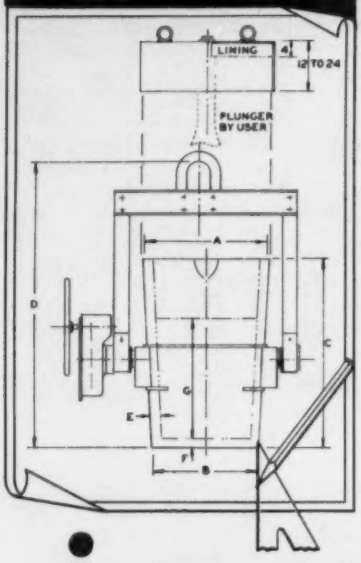
to lower costs
of ductile iron



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Circle No. 188, Page 15 or 145

Controls for Reducing Blast Cleani

In the average foundry, blast cleaning equipment varies widely in its operating efficiency. Even in supposedly good operations, blast equipment often operates at less than 50 per cent efficiency.

We have found where and why and how such inefficiencies insinuate themselves into a blast cleaning operation. Comprehensive (but not complicated) control programs for isolating these causes of inefficiency are now available.

■ The first set of controls are termed operating controls which are designed to check the efficiency of the machine. These include regular readings of the wheel motor ammeter, regular abrasive additions to the machine, periodic hot spot checks and regular screen analyses of the abrasive operating mixture and separator discharge. Operating controls make it possible to stabilize the blast cleaning operation so that subsequent cost control measures taken are meaningful and comparative from one period to the next.

Without proper ammeter readings, there is no true idea of how much abrasive is being thrown by the wheel. For instance, an operator may open the abrasive control valve wide to get what he thinks is maximum loading. But he succeeds only in choking the wheel and reducing its throwing to only 50 per cent of its rated capacity. Or, if the ammeter is not checked and loading on the wheel motor does fall off, cost figures would indicate reduced abrasive consumption; or that the abrasive was doing an inferior cleaning job by taking longer. Neither conclusion would be accurate because operating control was not constant.

■ Regular additions to the abrasive mix are important. In too many instances, the operator waits to add abrasive until he can't get the ammeter to show full load or until the machine stops cleaning. Then he adds a full charge of abrasive to the machine. In these moves, he has completely disrupted the very important ratio of large and small sized pellets in the abrasive mixture. The cleaning cycle suffers greatly.

Both sizes are needed. Large pellets knock off sand and heavy scale; smaller pellets are effective in removing the sand and scale loosened by the impact of the larger pellets.

Therefore regular additions to maintain the proper mixture are important to cleaning efficiency. Once the optimum mixture is established and recorded, any deviation will immediately indicate something is wrong in the operation.

We have found 2, 3, 5 and even greater percentages of sand in some operating mixes. Only 2 per cent sand will double total maintenance on the wearable parts in a machine and add substantially to over-all cleaning costs.

Screen analysis of separator discharge is also important. For instance, increasing the size of abrasive particles being removed by the separator just 0.005 in., from 0.011 in. to 0.016 in., increases abrasive consumption 30 per cent, regardless of the type of abrasive being used.

■ Once operating controls have been established, cost controls are easily instituted. Cost records should be expressed in cost per wheel-hour rather than in cost per ton cleaned.

First, this provides a common denominator for comparing cost records from one day or month or year, to the next. It is not subject to variations in product mix, cleaning difficulty, etc.

Secondly, it pins down operating costs—blasting hours. Whether a blast cleaner is working on a full load or a partial load, whether it is overcleaning or undercleaning, it is running. When the machine is running it's using up abrasive, wearing out parts and incurring all other costs required for operation.

Finally, cost per wheel-hour provides a basis for computing any type of cost figures required. Cost per ton cleaned, for instance, can be easily computed by dividing cost per wheel-hour by tons cleaned per wheel-hour.

The only accessory required for maintaining records on a wheel-hour basis is an hour meter which is installed in the wheel circuit. Then if a set of blades is installed, the control cage and impeller changed, or abrasive added, the wheel-hour meter reading is recorded and posted to a running log on each machine. This provides the basis for a sound, long-lasting cost control program.

■ Besides the control elements discussed thus far, there is a third element that must be present to make the controls work and obtain the cost savings that are possible. That element is management and supervisory

sts

by GEORGE O. PFAFF,
Wheelabrator Corp.
Mishawaka, Ind.

interest in lowering cleaning costs.

Management and supervision must become aware of the actual and potential operating condition of the machines, and must impress this awareness on operating and maintenance personnel. This support cannot be effective, however, if it is temporary, because blast equipment can deteriorate so rapidly that a temporary interest or program will have no lasting effect.

To help demonstrate management interest, our company has developed a series of training programs for both operating and maintenance personnel on airless blast equipment. The training program is an effective tool for showing management interest.

This article contains highlights abstracted from a paper presented at the 1959 AFS California Regional Foundry Conference.

AIR SETTING PROCESS

by DANIEL R. CHESTER
Archer-Daniels-Midland Co., Cleveland

■ The air-setting process was developed to provide a more efficient binder for making large cores. Overhang sections requiring backing sand and a recycling in the oven, cores requiring accuracy, and complex cores requiring a great deal of ramming and tucking have been continuous problems in the making of cores for large castings.

The process fits ideally in a jobbing shop making medium and large castings. It is not suited to a high production-type foundry because of the relatively slow turnover of any one core box. On miscellaneous castings, however, more tonnage can be produced per given amount of floor space and with a smaller, less skilled working force than by other methods.

The history of the air-setting process dates back to 1939 when the Otis Co. of Cleveland used the process to make the right angle uprights which support the Main Avenue bridge spanning the Cuyahoga River in Cleveland. In 1942 the French started to use the process. The Swiss solicited the trade in this country in 1949. Not until 1954 was a sincere effort made to work with the process. Since then nearly 700 foundries in this country have tried it. Possibly 400 are using the process in quantities from a single core to 70,000 lb of sand per day.

Next to cores the biggest use of the air-setting process is for dry mold facing backed up with regular molding sand. Some foundries bake their molds, others spray the mold with an alcohol wash, lighting off the wash and not baking the mold. The latter is especially true in gray iron. The heat from the alcohol wash plus the superficial heat from the metal have been found sufficient to produce a surface skin on the mold. Close tolerances have been one of the major advantages and, of course, no baking wherever possible.

Extensive research programs are presently aimed at producing a nonbaking, high tensile, good collapsibility-type binder. Also, the problems of climatic or operational conditions are being checked with the strong hope of minimizing these possible sources of trouble.

This article contains highlights abstracted from a paper presented at the 1959 Southeastern Regional Foundry Conference.

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MAKE YOU MORE

The heavy-duty industrial engines in Allis-Chalmers lift trucks stand alone in their ability to take tough work for long periods. The fact that they are the most rugged used in lift trucks means thousands of extra work hours, minimum maintenance, more years of service.

The fact that they deliver more usable horsepower means they do extra work every hour — maneuver faster, climb steeper grades. An Allis-Chalmers 2,000-lb truck, for instance, climbs a 40-percent grade loaded — other makes in the same class climb grades of only 18 to 28 percent.

Does the engine make a difference? Just listen to these users.

"They're brutes for punishment," comments a spokesman for a Michigan firm. "We formerly replaced an engine a year — haven't replaced any in the Allis-Chalmers trucks in over three years of operation."

No major engine overhaul under 10,500 operating hours for the 19 Allis-Chalmers trucks at a New York establishment. "We actually overhauled the first engine as an experiment — we wanted to know what made it tick for 10,500 working hours."

"They use less fuel than other trucks do," says a chief mechanic in Wisconsin. "Allis-Chalmers lift trucks also are tougher than others and require less maintenance."

Put an Allis-Chalmers lift truck to work and you will see many advantages of its heavy-duty engine *immediately*. But it will take years to reveal *all* the benefits. Let your dealer give you more facts — and a demonstration. Allis-Chalmers, Milwaukee 1, Wisconsin.

ALLIS-CHALMERS

BM-120

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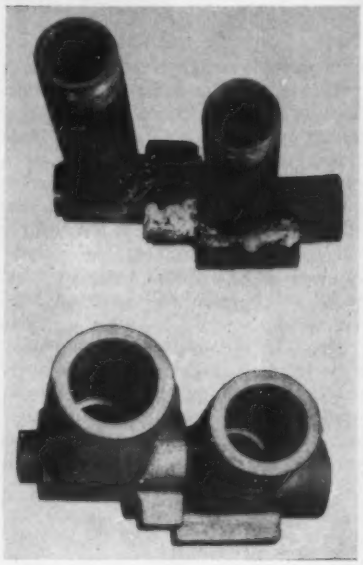
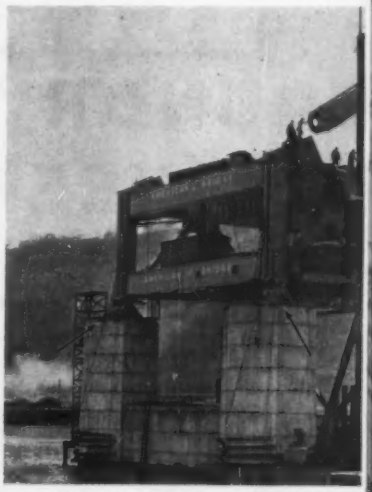
here's how

. . . **Chicago Malleable Castings Co.,** Chicago, Ill., redesigned a barricade bracket from an eight part weldment to an integrated malleable casting.



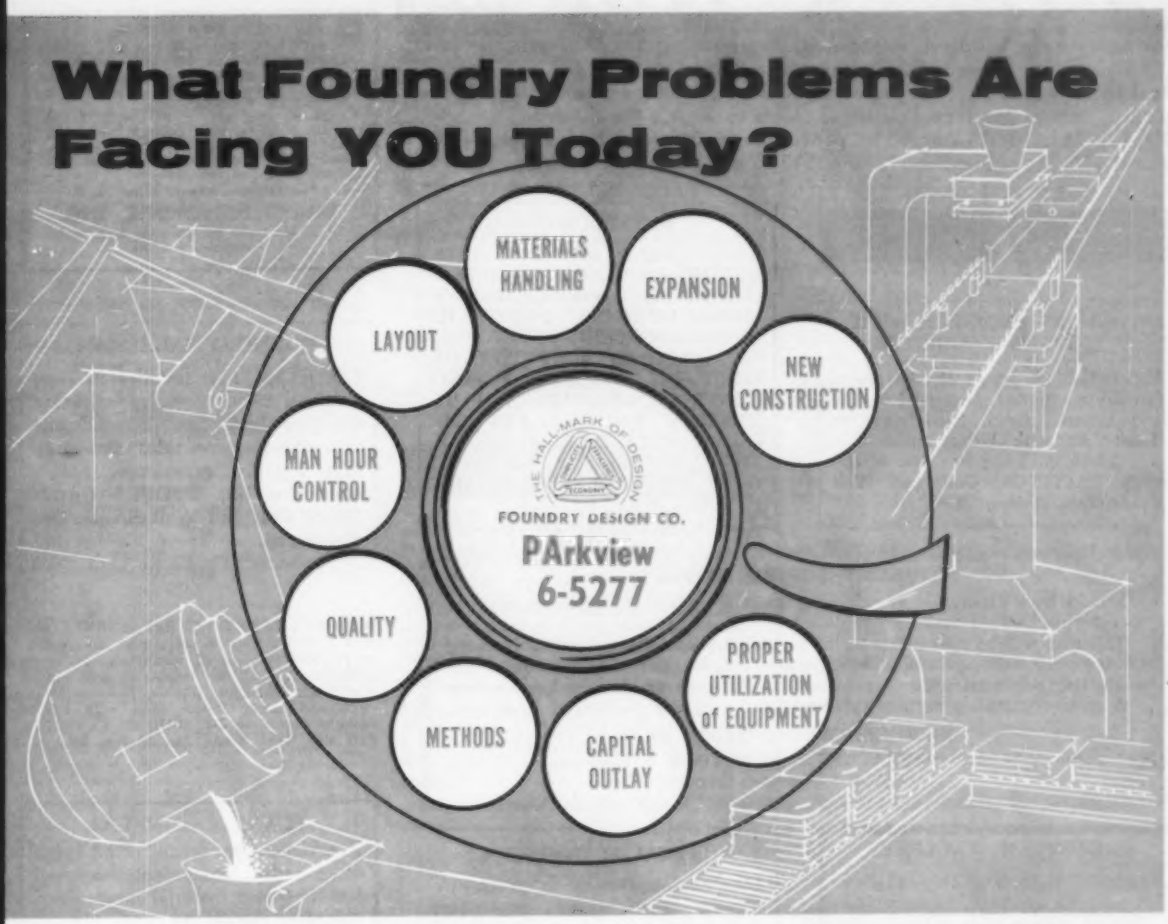
Made as two castings joined in the final assembly with two rivets, the cast parts have increased strength and are more functional.

. . . **Blaw-Knox Co.,** Pittsburgh, Pa., helped build the new Fort Pitt Bridge at Pittsburgh. Shown on top the masonry piers are two massive steel cast-



ings, each weighing 52,000 lb and measuring 10 ft x 8 ft 2 in. x 4 ft 6 in. They were cast by the Blaw Knox Foundry & Mill Machinery Div., Coraopolis, Pa.

What Foundry Problems Are Facing YOU Today?



THEIR *Answers* ARE AS CLOSE AS YOUR TELEPHONE!

By contacting Foundry Design Co., you may bring into your plant immediately a foundry engineering service developed by experienced personnel who can offer design ingenuity for special purposes adaptable to your operations.

At all times the objective is to achieve maximum efficiency and coordination in melting—molding—coremaking—cleaning. With such coordination, foundry deficiencies are remedied and production increased. Complete foundry production layouts utilizing existing equipment or guiding alterations, expansion or selection of new equipment are fundamental functions of our service.

Let us arrange for you to visit any of the companies who have availed themselves of our service.

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■ Radioactive sulphur was used to study the kinetics of desulphurizing molten iron with magnesium by V. I. Lakomskii. The experimental results were reported in Liteinoe Proizvodstvo, No. 11, 1958. Observations revealed that part of the sulphur in iron is carried away with the fume during the violent reaction between magnesium and iron.

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■ Condensed from a translation by H. Brutcher; circle No. 228, page 145, for a list of Brutcher Translations available for purchase.

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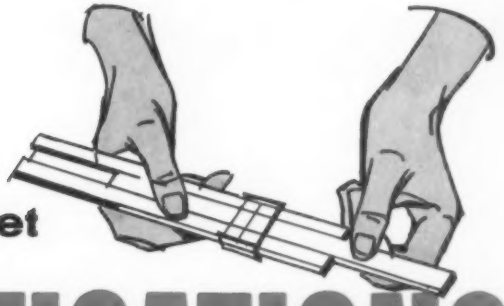
The patent states that the olivine sand displays a slightly greater permeability and a somewhat higher green compression strength. The overall similarity between the green properties of sand containing olivine flour and that containing silica flour is said to be surprising. *Pat. No. 2,822,278 issued to Harry W. Dietert and William M. Ball III, Detroit, Mich., and assigned to International Minerals & Chemical Corp., Chicago.*



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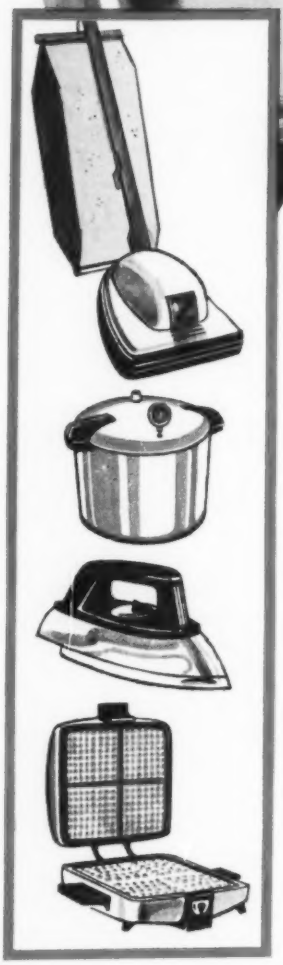

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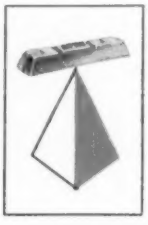

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